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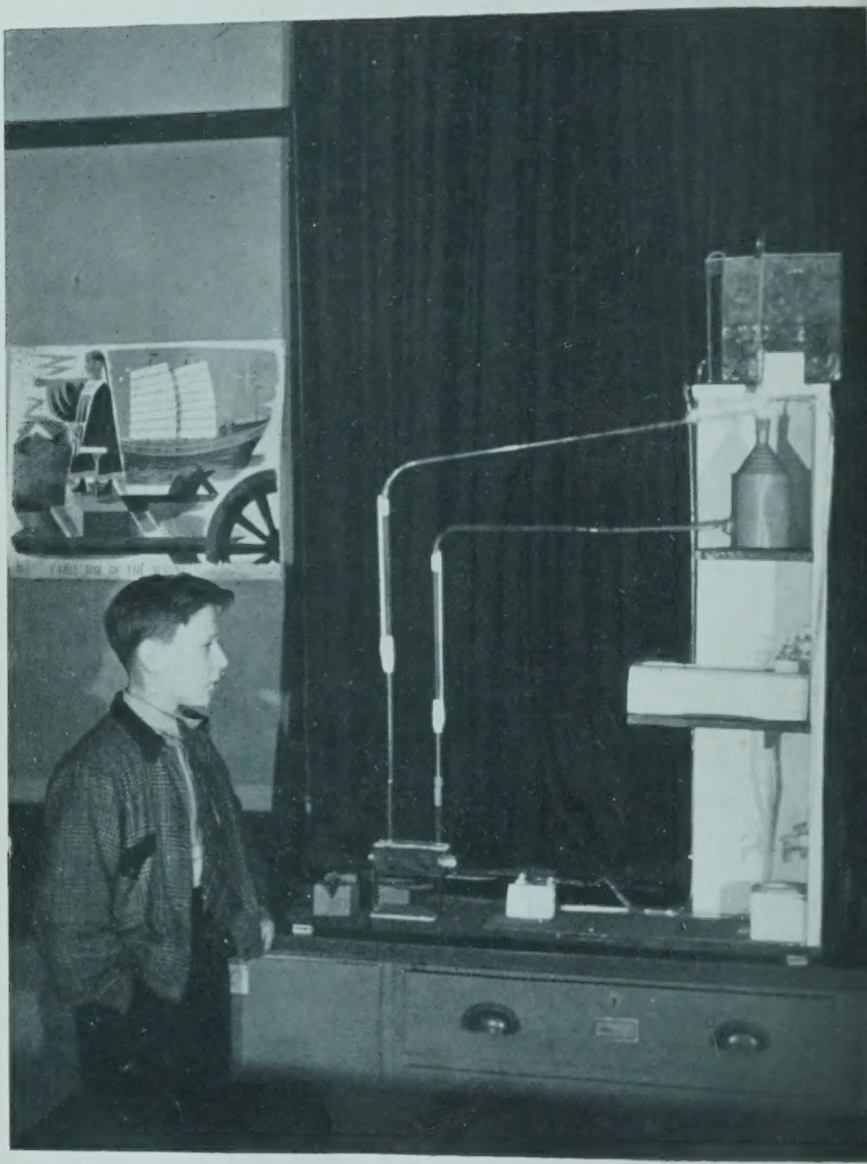
SIMPLE GLASS-BLOWING FOR LABORATORIES & SCHOOLS



A MODEL DOMESTIC HOT-WATER SYSTEM

(See page 98)

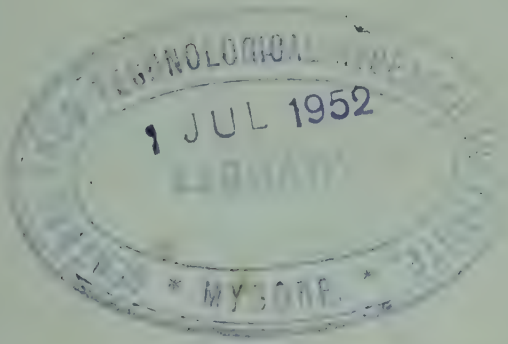
SIMPLE GLASS-BLOWING FOR LABORATORIES & SCHOOLS

BY

WILLIAM E. PARK-WINDER

Science Master of Lambeth Road School
Liverpool.

ILLUSTRATED



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PREFACE

I

This small handbook is intended to provide a number of practical suggestions for the working of glass to teachers of science and laboratory workers; especially the younger practitioners who have not had much opportunity to exercise their ability in this subject in the laboratory.

Those colleagues who have a measure of skill in the art of glass-blowing will readily testify to its great utility in laboratory practice. Not only in the construction of new apparatus, and in routine assembly, but also in the repair of broken glassware.

The text is written so that, with some assistance from the master or mistress, intelligent pupils from thirteen years upwards, can acquire a really useful and profitable technique in the art.

II

To those approaching the subject for the first time, it must be emphasised that the most valuable asset will be patience. A great deal of time is required, and at first, a substantial consumption of material. The practice closely resembles the first few months of pianoforte studies, when progress seems very slow; and, as in this subject, there is no short cut to success. Manual dexterity is only obtained by constant practice. It is desirable that the student practises a little each day, rather than for long periods at infrequent intervals. A knowledge of the Manufacture and Properties of Glass is considered essential to a good glass-blower. For this reason an appropriate chapter has been included. The Tables I and II occurring in this chapter have been borrowed from Professor W. E. S. Turner's Monograph on the subject, and abbreviated.

The Course of fifteen graduated lessons appearing at the end of the text provides a training scheme which gives, without previous preparation, a sound groundwork of glass manipulation.

W. E. P.-W.

ACKNOWLEDGMENTS

THE Author expresses his sincere gratitude to Mr. J. S. Towers, of Messrs. J. W. Towers and Co. Ltd., for his advice and for very practical help. To Professor W. E. S. Turner, O.B.E., D.Sc., F.R.S., for his kindness in permitting the use of extracts from his Monograph, "Elements of Glass Technology for Scientific Glass-blowers (Lampworkers)", and for his encouragement.

To the Advisors of the Liverpool Education Authority, for their numerous suggestions on the presentation of the matter in Schools, and a heartening interest in all phases of the experimental work. To Mr. F. R. Sistern, Headmaster, for the granting of many facilities; and to Mr. H. G. Weston, for many of the diagrams and experienced criticism.

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CHAPTER I

PRELIMINARY SUGGESTIONS

THIS chapter is concerned with advice and information regarding the general conditions necessary to predispose to good results.

The student should, as far as possible, be undisturbed by the passage to and fro of other workers. If a special room can be devoted to glass working, so much the better. If not, at least part of a laboratory or bench must be adapted for use. Windows in the vicinity must be kept closed or fitted with filters, as a current of cool air, although perhaps imperceptible to the worker, may ruin the work of many hours. A direct draught is much more serious.

THE TEMPERATURE OF THE ROOM.

This may seem at first sight unimportant, but is in fact of considerable consequence. A high temperature is uncomfortable for the worker although quite satisfactory for the glass. 70°F. is a good approximation and is generally found to be comfortable for the worker and not extreme for the glass. It might be thought that in a cold room the air would be locally warmed by the gas blow-pipe. That is so, but the trouble is caused by the ascension of hot air from the region of the blow-pipe, and the consequent flowing in of colder air to take its place. This frequently causes premature cooling in a part of a piece of apparatus temporarily removed from the flame.

'The colder the air in the room the more dense it is, and therefore, the more rapid is the rise of the heated air from the vicinity of the apparatus, and the greater the influx of cold air.'

LIGHTING. The glass-blowing bench should be illumined either by subdued natural light, or by shaded artificial light above the bench so as to avoid shadows. A window immediately in front of the bench is not desirable. Subdued light is necessary as it is essential to estimate the temperature of the glass by its colour.

SITTING AT THE BENCH. The bench must have a knee-hole sufficient in size to accommodate a foot-bellows. Its top must be low enough to allow the elbows of the worker to rest comfortably upon it; and the chair or stool should be of proportionate height.

Two feet six inches is a satisfactory height for a bench, and one foot six inches for the chair or stool. If the bench is fitted with shallow drawers on either side of the operator, so much the better.

THE SURFACE OF THE BENCH. The working surface should be covered with soft asbestos sheet over an area of two square feet. It is an advantage to have these tacked or screwed to the bench top, although of course they can be removed each time and the bench used for another purpose. The asbestos should be treated with a flat black dye or water colour. This presents a dull background against which the temperature of the glass may be gauged. It also avoids glare which in time can be very trying to the eyes: and is of great importance in providing a background, against which a fine pointed blue flame from the blow-pipe can be seen clearly.

Two half-inch diameter holes for gas and air tubes should be bored through the top of the bench, at about three or four inches from the front edge. The right and left-hand sides of the bench should be bordered with a strip of wood, the upper edge of which is shaped to allow tubes to be rested upon it. The best method is to bore a series of one-and-a-half inch diameter holes down the centre of a narrow board. Then saw it down the

middle through the holes and screw both strips on to the sides of the bench.

A one-foot square block of wood bored with holes of varying diameter, to hold hot glass tubes, is very useful and should be situated at the back of the bench in one corner. The bench surface should be kept tidy and free from glass fragments.

DISPOSAL OF GLASS FRAGMENTS.

Waste-paper baskets should never be used for the disposal of pieces of glass when glass-blowing. In schools and works, the cleaning staffs are seldom careful of their own hands and in helping a mass of paper out of a basket may sustain a nasty injury from a spindle of glass, quite apart from the risk of fire in throwing away a hot piece of glass. A large metal box like a biscuit tin serves well for the purpose, being readily distinguished, and is quite fire-proof.

THE GLASS-BLOWER.

Clothes. The operator should wear an overall or laboratory coat as a protective measure against pieces of hot glass, which occasionally crack off a hot tube or rod.

Burns. Burns sustained while glass-blowing should never be neglected, but treated immediately with tannic acid jelly or picric acid solution, supplies of which should always be at hand.

Eyes. After a period of glass-blowing the eyes may feel rather irritated and sore. This complaint may be dealt with by using warmed fresh milk in an eye-bath. A fresh portion of the fluid should be used for each eye.

RACKS TO HOLD GLASS TUBING AND ROD.

It is common practice in the glass-blowing 'corner' of the laboratory to store glass tubing on end, in boxes;

i.e. one end resting in a box on the floor and the other leaning against a wall. If the stock is rapidly used and replaced, this is quite satisfactory. If, however, the material is kept in stock for some time, as is usually the case in schools, it is best to avoid this method, and resort to storing in a horizontal fashion. For this purpose, a rack of height five feet, width two feet and length five feet eight inches, as shown in the diagram, should be constructed of wooden battens. The sides S, top T, and end B are closed in with sheets of three-ply wood. Shelves 1, 2, and 3 of spaced wood battens are screwed to the framework of wood battens forming the sides.

Fig. 1.—Vertical Storage

Perpendicular battens, A, C, D, etc., divide the three compartments in the middle. The six compartments so formed provide ample space for a selection of sizes of tubes and rods, both of which are usually supplied from the factory in five-foot lengths. This type of rack can be made to exclude dust, the primary consideration, and also places no bending strain on the glass as does the previously described method of storage.

A cloth cover hanging from the top of the open end and weighted with a strip of wood tacked to the lower edge of the fabric, completes the dust-free storage of tubing and rod in an orderly fashion. The cover is easily thrown back over the top to disclose the contents of the rack. An important feature of this method of

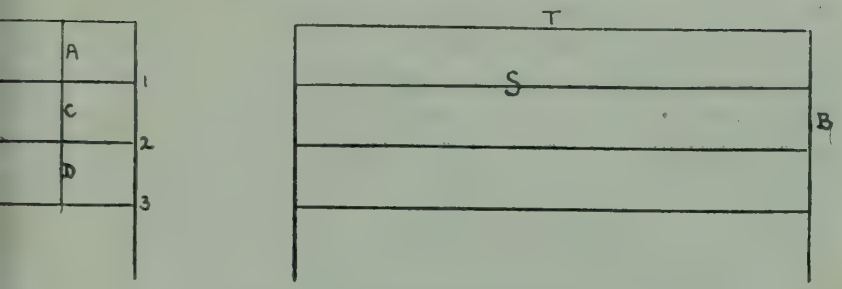

Fig. 2.—Horizontal Storage

torage, is the ease with which the diameters and thicknesses of the material can be instantly seen and measured.

'HE CLEANING OF GLASS TUBING.

It is essential that tubing used for glass-blowing is lean. Not only may a coating of dust lie on the outer urface, but where tubing has been stored on end for ome time, the inside may also be dusty. Certain salt eposits from the glass itself may also be present if the tmosphere of the storage room is damp. One of the ost satisfactory methods of cleaning glass tubing, is to eat it with dilute chromic acid solution. This is ttended by two major difficulties:

(*a*) the washing of five-foot lengths of tube with corrosive acid.

(*b*) the drying of the tube inside as well as outside.

n the author's school laboratory these difficulties were vercome as follows:

The tubing (which was always washed in full lengths nless of course, small pieces only were required) was laced inside a five foot length of two inch diameter ubing which had been sealed at the lower end. The tube as supported in a wooden stand, and filled with a ilute solution of chromic acid, prepared by grinding up rystals of potassium dichromate to a powder, mixing ith concentrated sulphuric acid, and pouring the mass autiously into water. (Rinse out the mortar into the

solution). A large number of four, six or eight millimetre diameter tubes, can be left in this tube of solution for a few days. They are then taken out, rinsed with clean water and dried. The process of drying is carried out in the following way: Air from a bellows is passed through a hard glass resistance tube about two feet long fitted with an asbestos stopper at each end, and wound with a five hundred watt nichrome resistance wire through which a current, sufficient to heat the wire to dull redness, is passed. Between the wire and the glass thin sheets of soft asbestos are included. Into the outlet end of the tube, an inch of asbestos fibre packing is pushed, to filter out any burnt dust particles blown in by the bellows. The arrangement of the drying apparatus is explained completely in the diagram; and provided the stream of air is constant, a rubber tube can be used to connect the apparatus to the glass to be dried.

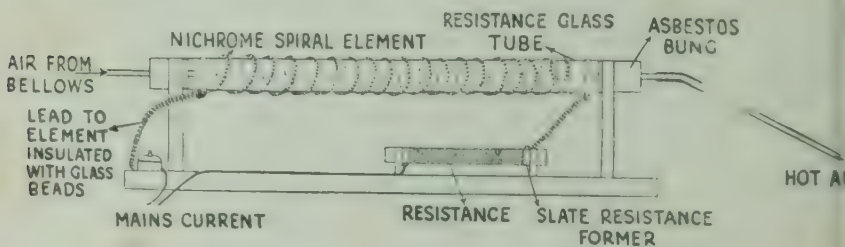

Fig. 3.—Hot Air Dryer for Tubes and Apparatus

CHAPTER II

GLASS-BLOWING TOOLS & EQUIPMENT

Coal gas and air, in a mixture of varying proportions, is used by the glass-blower to soften the glass. This mixture is burned in gas burners of differing types, from the humble Bunsen burner which can be used only for very simple operations, to the latest multiple-burner gas blow-pipe.

At this stage it will be advisable for the young student to dismantle a Bunsen burner, and examine the device whereby air is mixed with the gas. Air is introduced and mixed with the gas by the rapid passage of the latter through the jet B, causing a suction effect at O. The explosive mixture of gas and air then burns at the top of the tube.

The Bunsen burner can be used for simple tasks such as rounding off sharp edges; but for bending tubes and for glass-blowing, a batswing or fishtail burner and blow-pipe respectively must be used.

The Batswing or Fishtail Burner.

This burner has no inlet for primary air, and the direct contact of the gas with secondary air is its only means of burning. The design of the fireclay jet at the top of the tube enables the gas to suck in some air, and to form a thin fan of flame. This wide flame heats uniformly along a length of about four inches, making it possible to form good curves in glass tubes.

The Gas and Air Blow-Pipe.

This is an apparatus into which primary air is blown under pressure, from either a foot-bellows or a mechanical pumping device. The air is emitted from a jet; of which

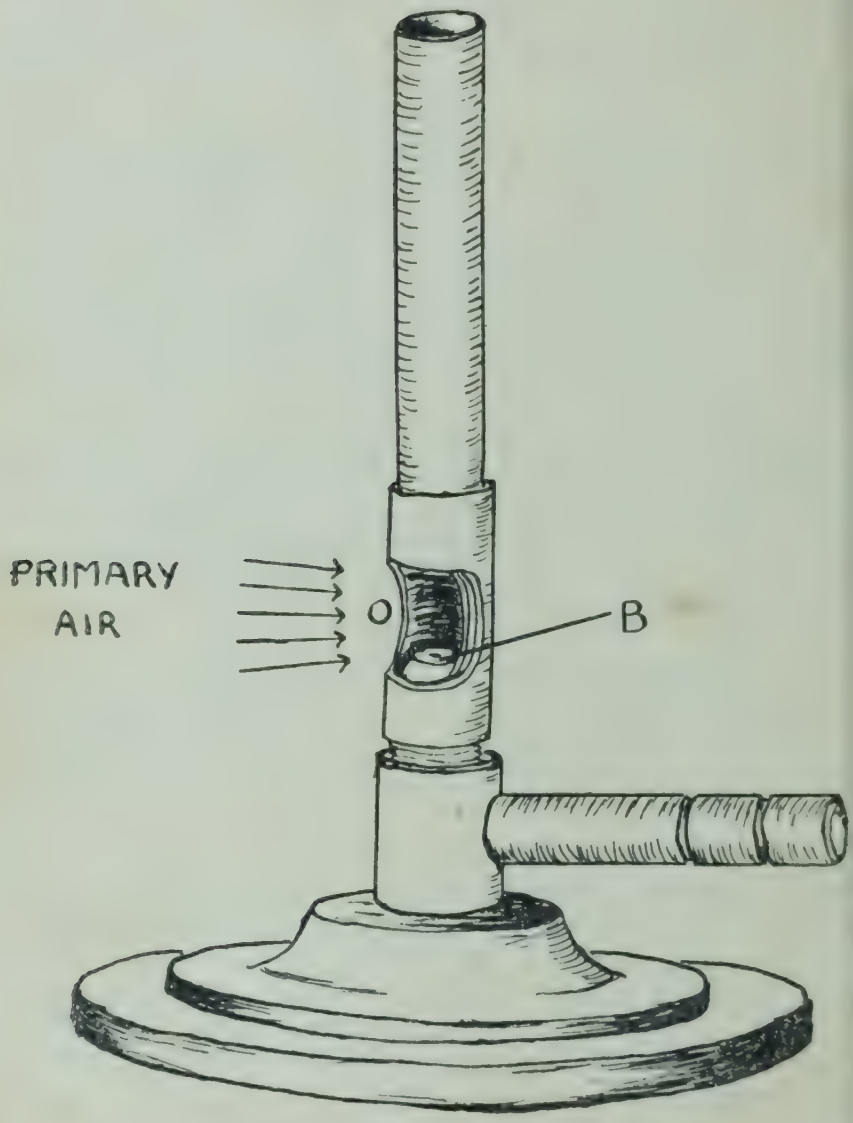

Fig. 4.—The Bunsen Burner

there are usually about three, of differing sizes, into a tube through which gas is passing. Both the air and gas are controlled by individual taps on the body of the

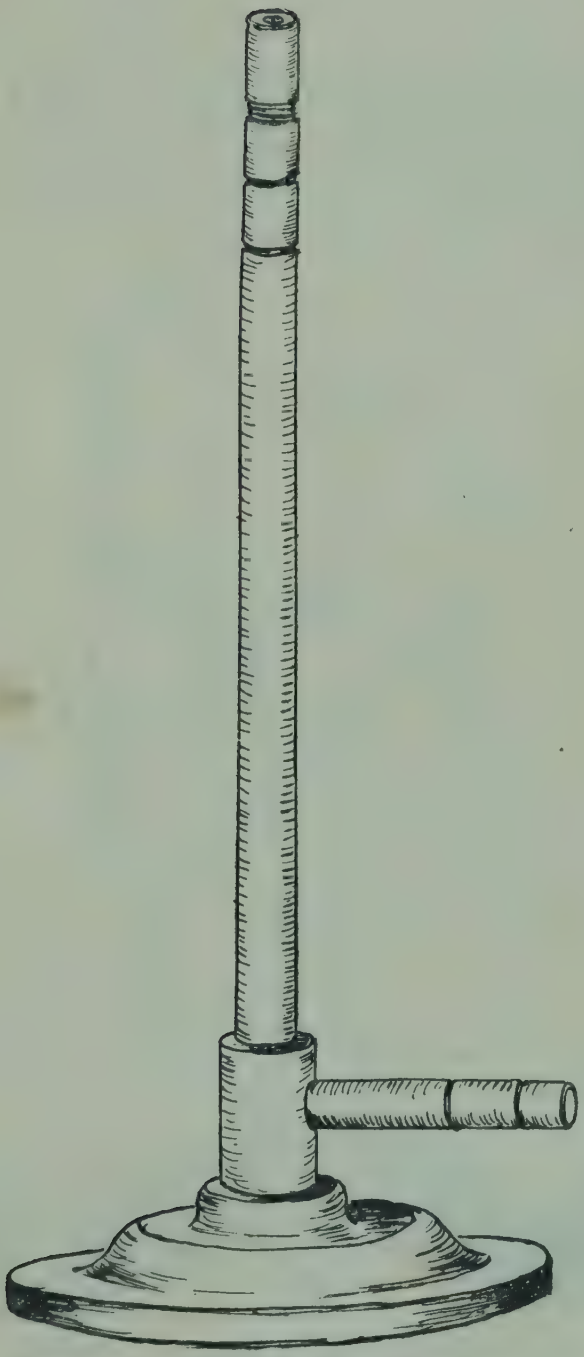

Fig. 5.—The Fishtail or Batswing Burner

apparatus, and can thus be adjusted until the mixture gives sharp pointed blue flames varying in size, or brush-like flames of any desired size. The air can instantly be cut off to give a large luminous flame for annealing purposes.

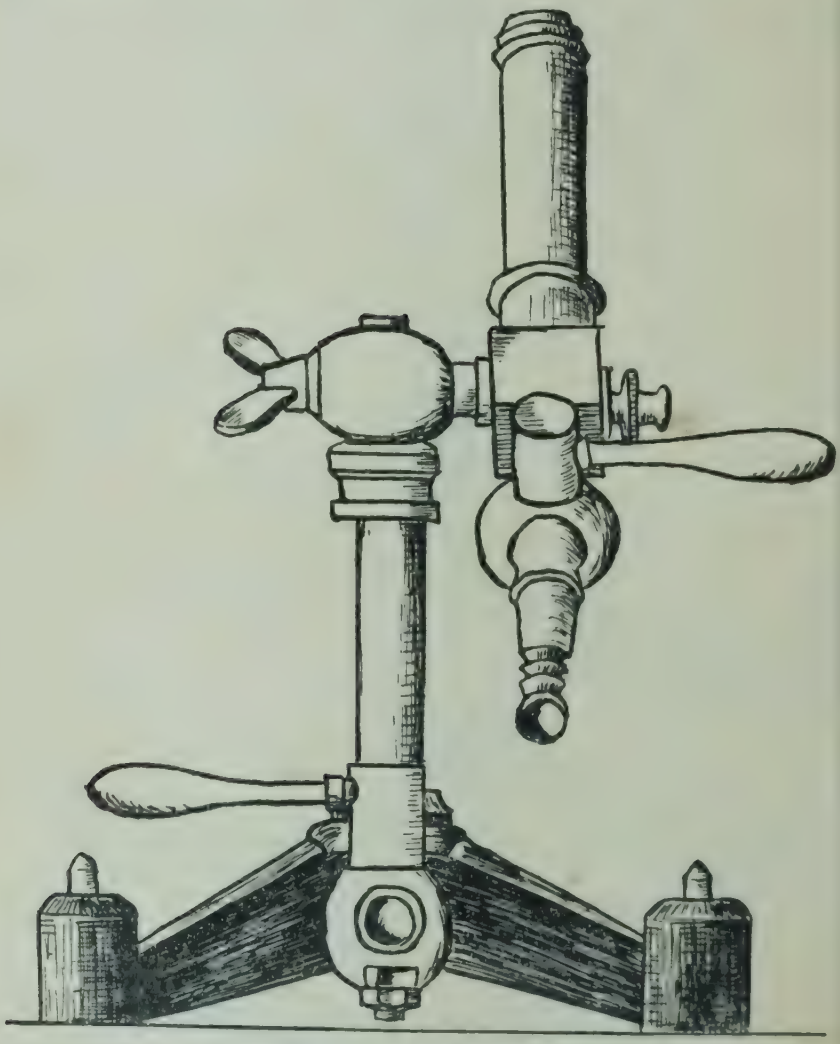

Fig. 6.—The Gas and Air Burner or 'Blow-Pipe'

An annular sleeve which may be advanced or retracted is present on most blow-pipes. The effect of the movement of this on the flame may best be studied by actual practice. Notice the effect of connecting up the gas and air supply to the wrong tubes. Advance the sleeve until the open end is about half a centimetre in front of the inner air nozzle (or jet).

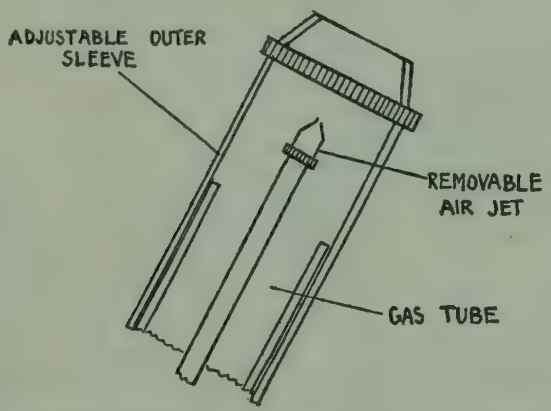

Fig. 7.—Cross Section of Gas and Air Blow-Pipe.

Obtain the various types of flame; from the large luminous type derived by cutting off all the air, to the small pointed blue flame, for fine localised heating. Flames of the type shown in (*a*), (*b*) and (*c*) of Fig. 8 can of course be reduced in size by:

(*a*) simple adjustment of gas.
(*b*) equal adjustment of gas and air.
(*c*) adjustment of gas and air.

The pointed blue flame depicted in (*d*) is for fine localised heating, using a smaller nozzle (or jet).

Before attempting to use the blow-pipe a young student should take it to pieces and re-assemble it, noting that the air jet is removable, and two different jets which are usually screwed loosely into the base can replace it as required. Some glass-blowers reject these and make glass jets of their own which they fix into the

NO AIR
(a)
FULL AIR AND GAS
WIDE NOZZLE
BRUSH FLAME.
(b)
FULL AIR AND GAS
FINER NOZZLE.
(c)
(d)

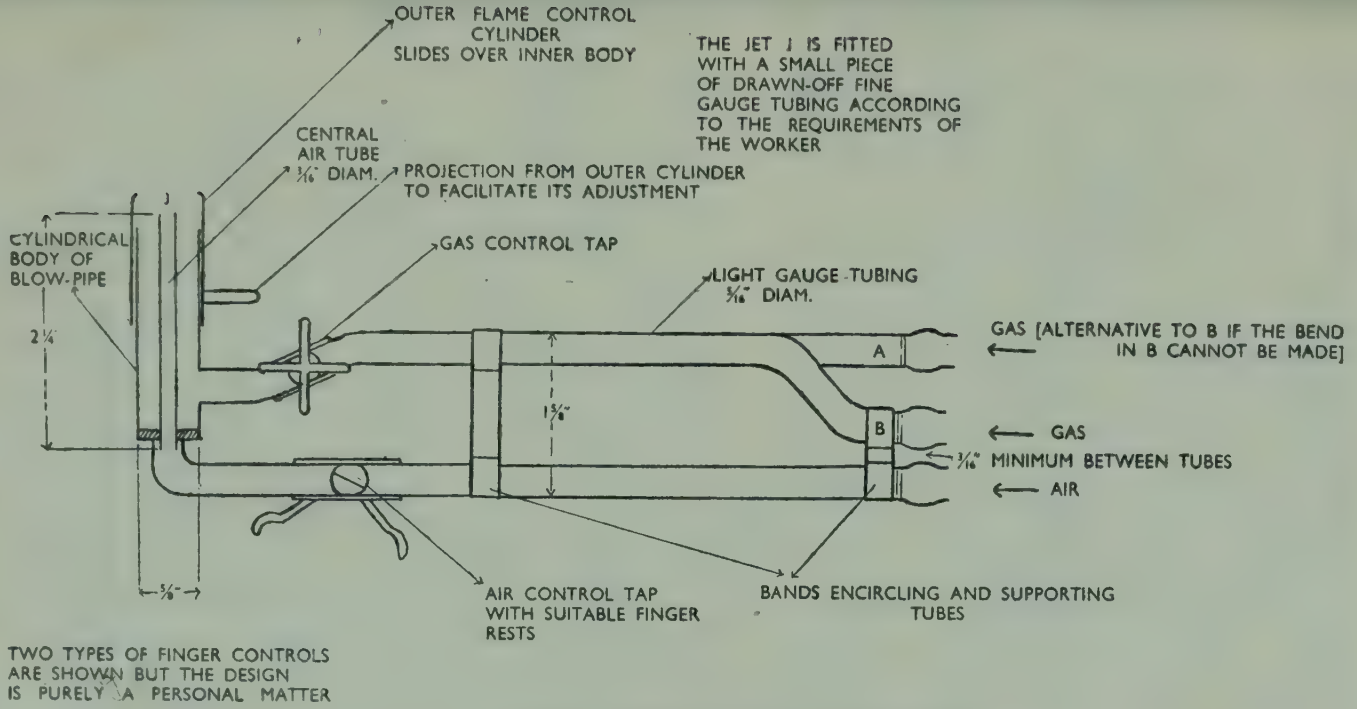
OUTER FLAME CONTROL CYLINDER SLIDES OVER INNER BODY
THE JET J IS FITTED WITH A SMALL PIECE OF DRAWN-OFF FINE GAUGE TUBING ACCORDING TO THE REQUIREMENTS OF THE WORKER
CENTRAL AIR TUBE 1/16" DIAM.
PROJECTION FROM OUTER CYLINDER TO FACILITATE ITS ADJUSTMENT
CYLINDRICAL BODY OF BLOW-PIPE
GAS CONTROL TAP
LIGHT GAUGE TUBING 5/16" DIAM.
2 1/4"
1 3/8"
A
B
GAS [ALTERNATIVE TO B IF THE BEND IN B CANNOT BE MADE]
GAS
3/16" MINIMUM BETWEEN TUBES
AIR
3/8"
AIR CONTROL TAP WITH SUITABLE FINGER RESTS
BANDS ENCIRCLING AND SUPPORTING TUBES
TWO TYPES OF FINGER CONTROLS ARE SHOWN BUT THE DESIGN IS PURELY A PERSONAL MATTER

Fig. 9.—Hand Lamp for Work in Situ

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tapped hole with paper. Very fine pin-point flames can often be obtained by this method.

THE HAND BLOW-PIPE OR HAND LAMP.

This works on exactly the same principle as the bench blow-pipe described above. The only difference being that of structure. The heavy base essential to the bench type is absent, and the gas and air controls are adapted to fit the index finger of the hand in which it is held. The hand lamp is usually made of light gauge brass, so that its weight is reduced to the minimum. The only consideration being the drag of the tubes connecting the gas and air supplies. The usefulness of this type of burner will be appreciated when the student is later assembling a large piece of apparatus which cannot be handled; or is making joints in an awkward position.

A PRECAUTION.

It is always wise to have an idle flame burning on the glass-blowing bench, as in adjusting the gas or air on the blow-pipe, the flame may accidentally be turned off while a piece of work is in hand. Sudden cooling, and stoppage of work in this way may result in strains being set up in the glass, with consequent cracking, either there and then, or upon re-heating.

THE AIR SUPPLY.

The air may be supplied under pressure to the blow-pipe by:

(*a*) a foot-bellows.

(*b*) a motor-driven air compressor.

(*a*) The bellows is too well-known to require much description. The Fletcher type shown in the illustration with an iron foot pedal, will suffice for most exercises. Under the framework of the bellows, a circular rubber diaphragm receives the compressed air and allows it to escape through a metal side tube.

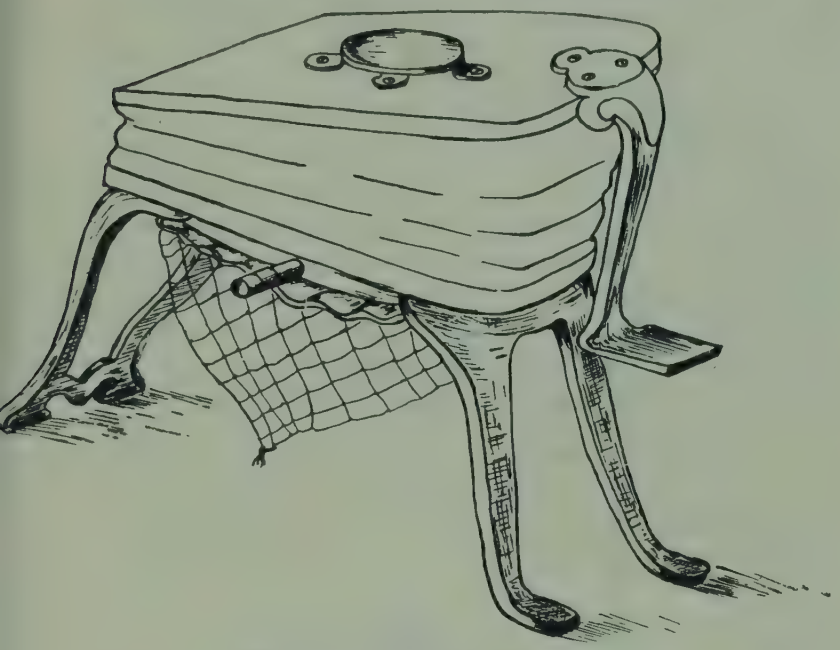


Fig. 10.—The Foot Bellows

(*b*) An air compressor is a refinement which leaves the oot of the operator free, and supplies an unbroken tream of air at a constant pressure, the volume of which an be adjusted using a resistance, by switching lamps n and out of the circuit, or preferably by a rheostat.

An apparatus of the following design was built and sed in the author's laboratory: Fig. 11 shows the ircuit diagram of the motor which is a universal, one ighth horse-power type with fan cooling. It is con-ected by a flexible drive, a piece of strong rubber ubing, direct to the shaft of a two-throw eccentric ump in turned brass. The pump is fed continuously by n automatic device with a thin lubricating oil, and this s separated from the compressed air, before the latter asses into a rubber reservoir (a football bladder). A amp in the circuit acts as a resistance, and can be re-laced by a null resistance bayonet plug. The apparatus

is portable, and similar machines are sold complete for glass-blowing purposes.

THE AIR PRESSURE MANOMETER.

It is convenient, whether the electric blower or the bellows is used, to have some means of showing the air pressure. If a constant pressure is kept up the blow-pipe flame is unvarying, and can be depended upon not to suddenly jerk, increase or diminish. This is most important in very fine work. For an assistant supplying air from a foot-bellows, a manometer placed in front of him gives an absolute indication of the pressure at any

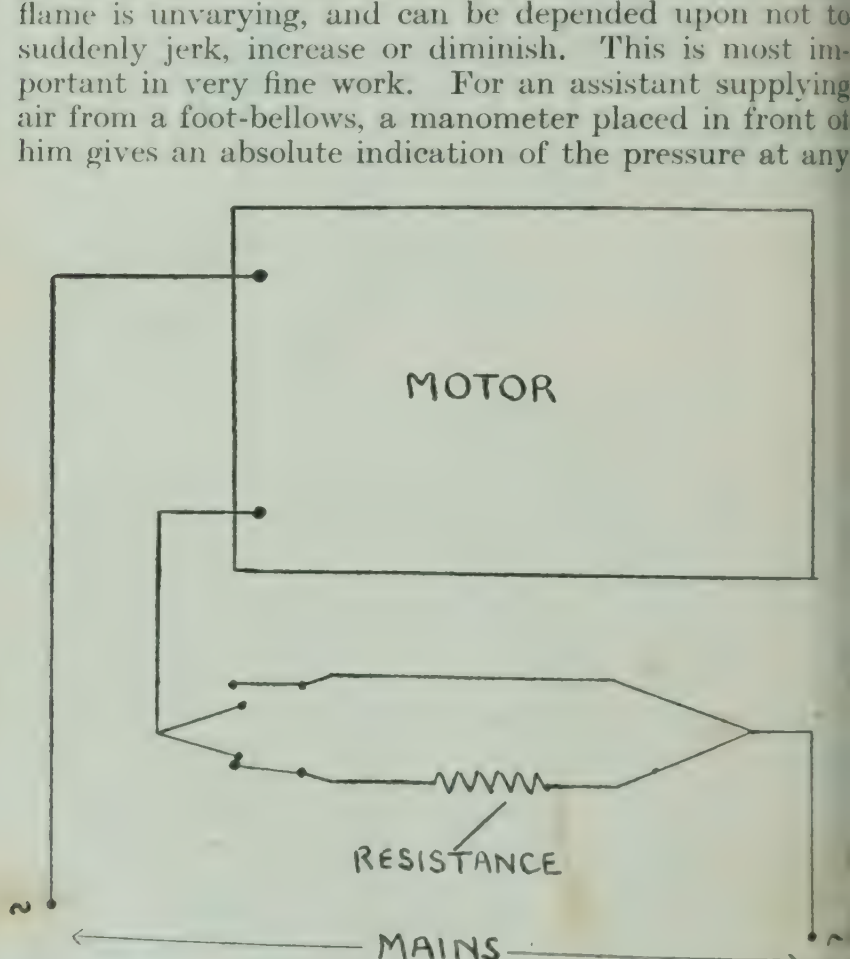


Fig. 11.—
Circuit Diagram of Connections to Motor of Air Compressor Unit

ime, and a mark made on the tube serves as a guiding oint.

Professionals find a pressure of about two pounds per quare inch satisfactory for most purposes.

LASS CUTTING.

All the work of the scientific glass-blower is done sing glass tubing of varying diameters. Small gauge ubing up to about ten millimetres diameter, and rod,

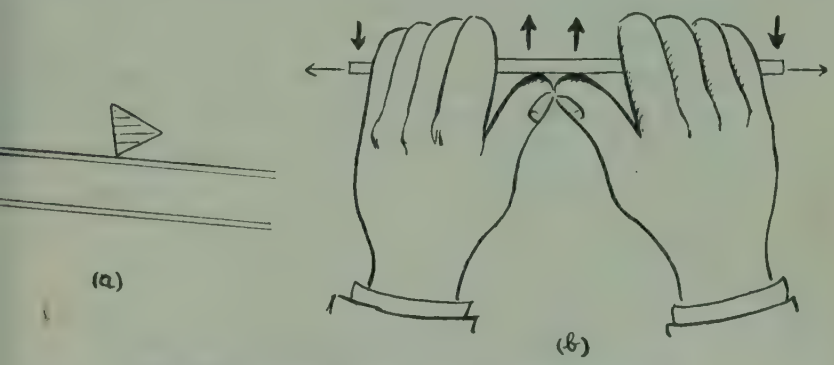


Fig. 12.—Glass Tube Cutting, using the File.
(*a*) The Position of the File.
(*b*) The Position of the Hands.

an quite easily be cut with a triangular file. The method s to press the file against the tube at the angle shown in a) Figure 12 and, keeping the pressure up, to run it along bout a quarter of an inch, so that it makes a small cratch in the surface of the glass. The tube is then ripped with both hands, and with both thumbs meeting nder the file cut, as in (*b*). It is then pulled slightly long its length, in the directions of the arrows and bent" away from the cut, in the direction of the double rrows.

The preliminary scratch can also be made with a ardened steel glass-knife, which is pressed across the urface of the glass in the same way as the file. Although entioned last, the glass-knife is superior to the file.

This advantage, however, is outweighed by the fact that a good knife is not as easy to obtain as a triangular file. Furthermore, the knife must be sharpened on a carborundum wheel or grindstone. Files wear out quickly and must be discarded, but can be purchased very cheaply and without difficulty.

CUTTING WIDE TUBES.

Tubes of diameter much greater than ten millimetres will be found rather awkward to cut in the way previously described. They may be cut satisfactorily by:

(*a*) Scratching all round the circumference and applying the red-hot point of a drawn-off piece of thin glass rod. Then following the crack round with the re-heated rod.

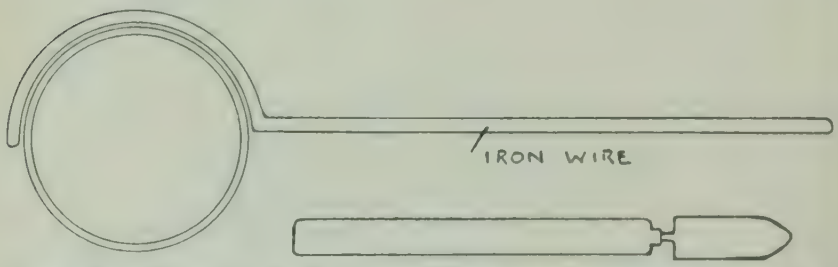


Fig. 13.—The Glass-Knife. Above: Wire for Cutting Wide Tubes

(*b*) Bending a length of nine S.W.G. iron wire, to curve round half the perimeter of the tube, leaving a long handle to the wire. The wire curve is heated to redness and placed symmetrically over a scratch. The tube may be carefully rotated as the wire is applied, and the crack flies completely round the tube giving a clean cut. It is convenient to make a number of these wires of differing size, ready for use.

For quickly cutting a number of large diameter tubes, a yard or so of nichrome resistance wire, in series with a fixed resistance, and connected with

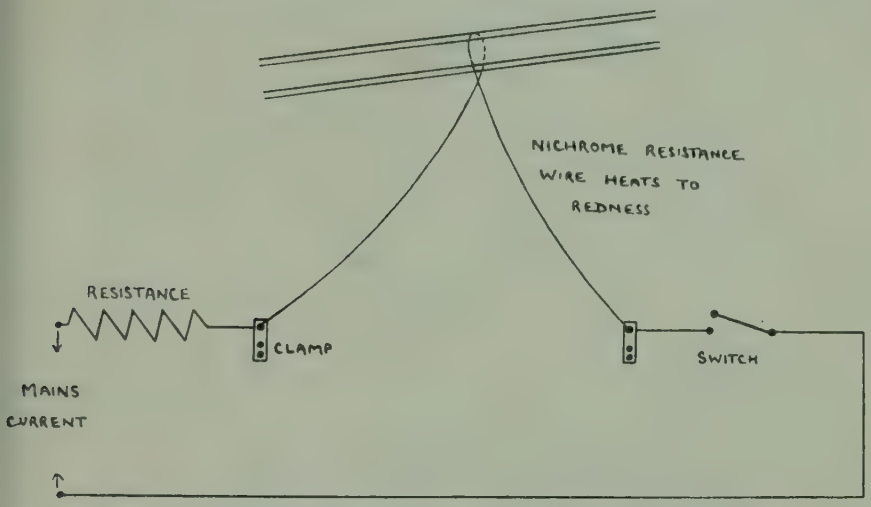


Fig. 14.—Electrical Method of Cutting Glass Tubing

a convenient switch to the electricity mains, is effective. A scratch is made on the tube in the usual way, and the wire looped round the tube over the cut, held taut, and heated by switching on the current. The resistance should be adjusted to pass a current sufficient to heat the wire almost to dull redness.

FOR CUTTING BOTTLES OR VERY WIDE TUBES.

The bottle or tube is mounted on two supports, or on a turntable, (an old clockwork gramophone serves excel-

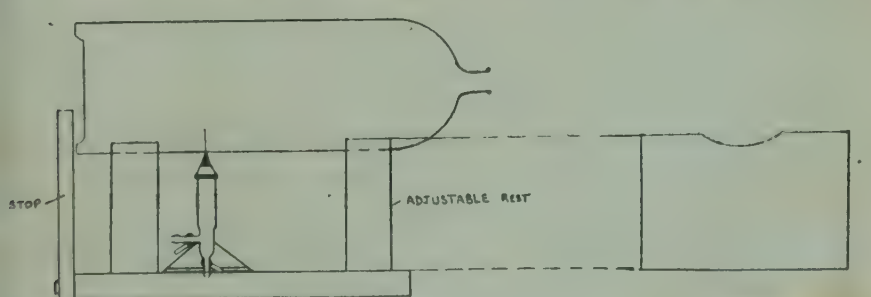


Fig. 15

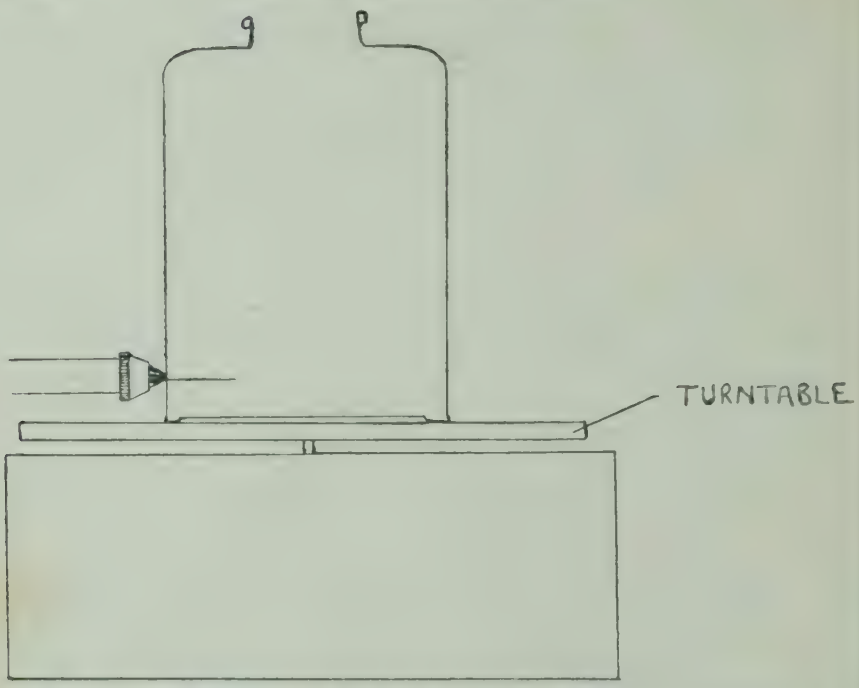


Fig. 16.—The Turntable Method of Cutting Bottles and Cylinders

lently), and rotated, after making a scratch at the required place. While rotating, a minute point of flame, about two or three millimetres long, is allowed to play along the side at the level of the scratch. This is a reliable method if executed carefully.

DRAWING OFF.

The professional dispenses with cutting where possible, and 'draws-off' instead. That is, heats the tube at the point at which he wishes to divide it and, as it softens, pulls it apart quickly. It must be emphasised that in order to heat the one portion of the tube uniformly, so that it pulls away quickly, the tube must be rotated in the fingers continuously. When the glass is soft, the tube should be removed from the flame and pulled in opposite directions as indicated in Fig. 17.

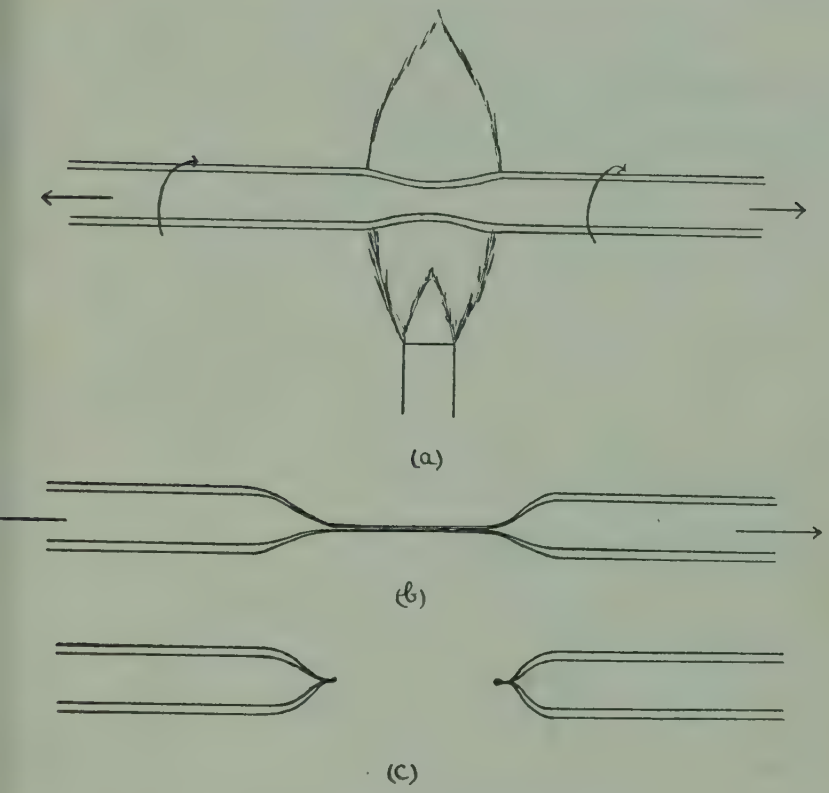


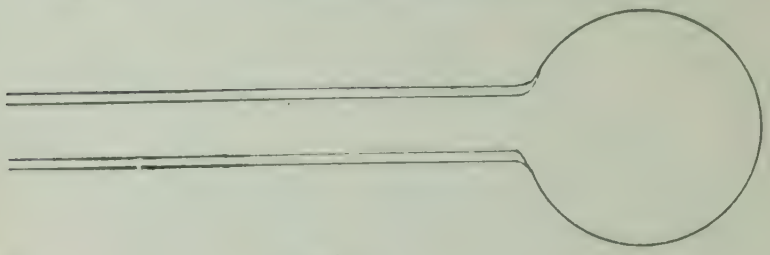
Fig. 17.—Drawing-off Glass Tubing

REATMENT OF THE ENDS OF TUBES.

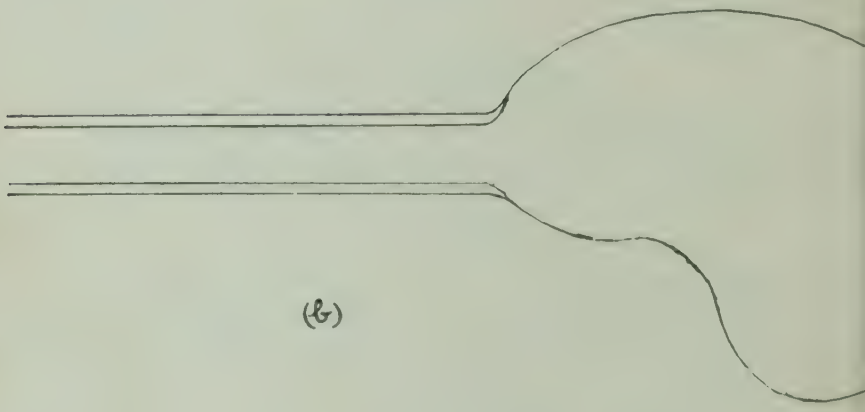
Small diameter. This type of tube can be treated to nish' the open end in three usual methods.

(*a*) Cutting off a ragged end with a file or glass knife. An inch or more must be cut off to allow for sufficient leverage for the fingers. The required end is then 'fire-polished', i.e. the tip rotated in a blue flame until it loses its sharpness.

Caution. Do not hold the tube in the flame until the bore constricts, it must remain the same diameter as the rest of the tube.



(a)



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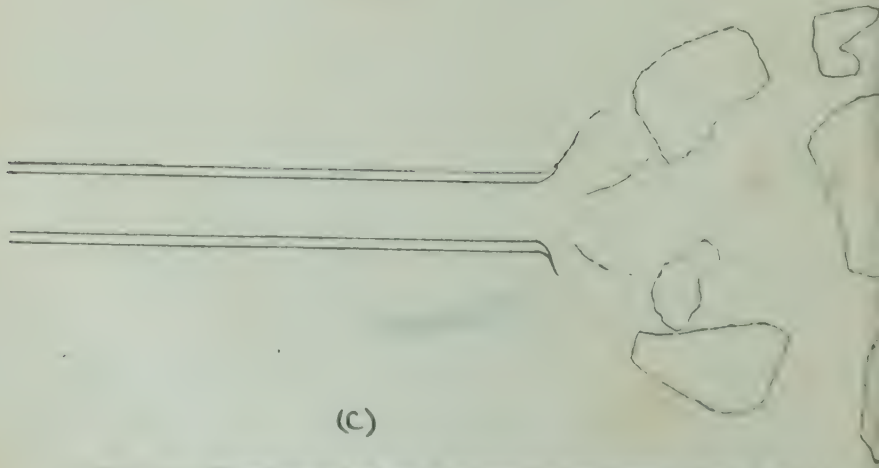


(c)

Fig. 18.—Blowing-out as an Alternative to Cutting Glass Tubing.

(*b*) Cutting off with a file or glass knife as before, then grinding smooth on a carborundum wheel.

(*c*) Drawing off, snapping off the capillary and sealing the required end. Heating strongly, rotating in the fingers and blowing out until a paper-thin bubble appears (*a*) or the glass forms a kidney-shaped bubble (*b*) or simply bursts into a film of glass which floats off into the air (*c*). In each case the thin glass form is broken away with a file, and any projecting pieces knocked off. The rough end is then fire-polished as before.

Large diameter.

(*a*) When a large diameter tube is cut in the way previously described, it may be fire-polished by rotating the edge of it in a blue flame, or by grinding it carefully on a carborundum wheel.

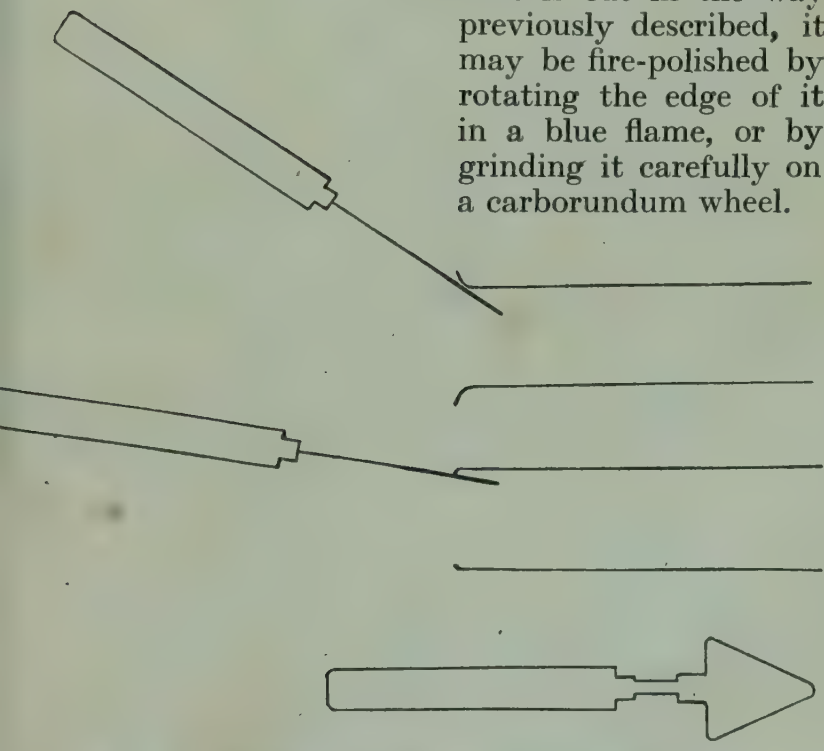


Fig. 19.—Treatment of Rims with the Rimming Tool.

(*b*) Such a tube may have its end spun or rimmed ou to a trumpet form, as on beakers, etc. This is effec ted by heating the rim of the tube uniformly, ro tating continuously, and pressing it outwards fron the inside by means of a simply made tool (shown in the diagram), the blade of which has bee warmed and rubbed over with paraffin wax o bees wax.

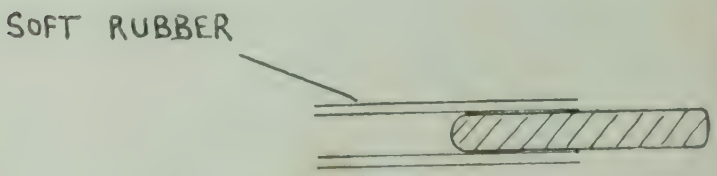


Fig. 20.—Tube Stopper

OTHER REQUISITES.

(1) An assortment of small and large bark corks.

(2) A number of short pieces ($1\frac{1}{4}''$) of black india rubber tubing with one end blocked by a sma piece of glass rod. These plugs ar useful for stopping up the ends o glass tubes, when air pressure is re quired inside them.

(3) A three foot length of $\frac{5}{16}''$ black strong walled india-rubber tubin fitted with a glass mouthpiece at on end, for use as a 'blow-tube'.

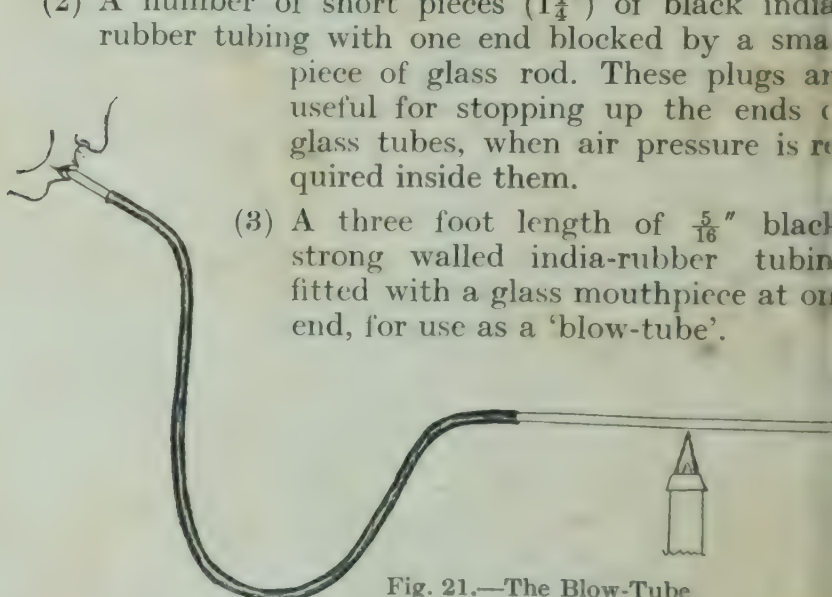


Fig. 21.—The Blow-Tube

CHAPTER III

THE MANUFACTURE AND PROPERTIES OF GLASS AND ELECTRODE SEALING

IF a mixture of soda and sand is strongly heated, the soda melts, and the sand dissolves in the liquid. The result is sodium silicate. If an excess of sand is used, the product is water-glass (sodium metasilicate), a glass which dissolves in water. This type of glass affected by water, would be of little use in the form of glass-ware, so that the addition of certain chemicals such as lime is resorted to. The presence of lime in sodium silicate makes it a substance insoluble in water, and unaffected by most reagents, particularly acids.

It is only of recent years that the layman has realised that glass is not a substance of constant and fixed composition, having a typical unvarying quality. He realises that the glass dish in which his meals are cooked has qualities differing from those of the windscreen of his car, or the windows of his house. In fact, hundreds of different types of glass have been made, and each one has its own peculiar characteristics, with its uses in the arts, in commerce or in science. Some of the most striking achievements in interior decoration of buildings have been executed in glass, in the form of tiles, rods, and panels in many colours.

The electric lamp and radio valve industry require their own particular qualities of chemical and heat resistance, softening points, and thermal expansion of glass. So do the makers of scientific apparatus, requiring glasses which fuse to different metals and to different glasses, etc. (See Table II).

With this huge field of widely differing requirements,

the glass industry has applied strict scientific control to all aspects of the production of glasses, which are now described in accordance with their constituents. For example, the alkali lead-oxide silica glasses, boro-silicate and soda-lime-silica glasses.

The composition of glasses, especially those used for scientific work, consist of mixtures in different combinations, of oxides of Sodium, Potassium, Silicon, Boron, Lead, Calcium, Magnesium, and Aluminium.

Table I gives the composition of lead glass and soft soda glass.

TABLE I

Constituent Oxides.	*Lead Glass*	*Soft Soda Glasses.*		
Silica . .	56.6	69.4	68.2	70.5
Alumina . .	0.8	3.8	4.0	1.6
Boric Oxide .	0.2	——	0.7	——
Lead Oxide .	30.2	——	——	——
Lime . . .	——	6.4	5.5	6.8
Magnesia . .	——	——	2.2	3.5
Soda . .	5.1	13.8	17.0	16.9
Potash . .	7.2	6.5	2.2	0.7

The chemical composition of a good glass may be stated as $A_2CaSi_6O_{14}$, where A represents sodium or potassium, or both. Ordinary glass, however, is usually rendered more fusible by its containing less silicic acid.

Glass is amorphous, as is indicated by its isotropic nature and the fact that it has no fixed melting point.

COLOUR OF GLASS.

Calcium and alkali-silicate glasses are colourless. In the cheaper kinds of glass, iron is invariably an impurity and gives the green, black-green, or brown colour which is often seen in bottle glass.

Sodium Sulphate being cheap, is sometimes employed in place of sodium carbonate, and in the presence of

charcoal, which is added. Sodium sulphite is formed, and this is more readily converted by the silicic acid present into silicate. Glass of this type contains sodium sulphate and even the sulphide, hence it will be understood that under certain circumstances, appreciable errors in accurate chemical estimations can be obtained. Cobalt oxide produces blue glass. Iron oxide, as previously described, produces a yellow-to-brown glass. Copper and chromium oxides, a green glass, and manganese dioxide a violet glass.

Certain metals also dissolve in glass in a colloidal state and give, in this condition, brilliant and intense colours. Silver gives a strong yellow colour. Copper or gold produce a deep red colour. A strong yellow-brown colour is obtained by dissolving charcoal in the molten glass. Calcium phosphate or tin dioxide will not dissolve in the molten glass, giving it an opaque white appearance. This produces what is called milk glass, frequently used as a background for viewing graduations on scientific glass-ware.

TABLE II.

PERCENTAGE CHEMICAL COMPOSITION OF SOME MODERN GLASSES.

ss	SiO_2	B_2O_3	AL_2O_3	Fe_2O_3	CaO	MgO	ZnO	Na_2O	K_2O	As_2O_5
. .	80.1	12.0	3.0	0.08	0.02	—	—	3.9	0.32	0.2
. .	80.6	12.2	2.7	0.06	0.12	—	—	4.2	—	—
. .	76.7	11.1	2.6	0.14	0.4	—	2.4	4.8	1.5	—
l" .	65.0	2.7	5.6	0.06	6.8	—	5.6	13.0	0.8	—
gn Tube	67.5	0.7	3.8	0.1	5.5	1.2	—	18.7	2.0	—
Bulbs & g	72.0	—	1.0	0.1	6.5	2.9	—	17.0	0.1	—

THE MANUFACTURE OF GLASS.

In earlier times, very rough rule-of-thumb methods were used for making the mixtures for fusion into glass. To-day the proportion of each constituent is carefully calculated.

Salts and minerals yielding the required oxides when heated, may be tabulated as follows:

Substance.	*Oxide Produced.*
Sand	Silicon
Limestone	Calcium
Felspar	Aluminium, Potassium
Sodium Sulphate, Sodium Carbonate	Sodium
Potassium Carbonate	Potassium

These raw materials, together with a calculated quantity of clean scrap glass known as "cullet", are first maintained for some time at moderate heat, so that the silicates are formed, but no fusion only sintering, occurs. This method is resorted to, in order to prevent the evolution of carbon dioxide gas from throwing the glass out of the heating "pots" or the furnace. The "frit" as it is then called, is melted by increasing the temperature, and this temperature of fourteen hundred to fifteen hundred degrees C. is maintained for a time sufficient to allow all the bubbles of gas to escape, and any undissolved materials to sink to the bottom.

In the tank furnace, which is usually of the Siemens regenerative type, the producer-gas burners which are the source of the heat, are arranged above the raw materials. These are fed into the furnace continuously at the hotter end, and flow to the cooler end of the furnace, where the glass is extracted.

When glass is to be worked in moulds, it is used in a thin condition from the furnaces. Most often, however, it is blown, that is shaped, with the help of surface tension. For this purpose it is cooled slightly until it becomes more viscous.

To 'blow' glass, a certain accurately judged quantity of viscous glass is taken up on the end of an iron tube called the blow-pipe, and with puffs of air it is blown out

ke a soap bubble. It is then shaped by a combination
f centrifugal force and gravitational force, or rolling on
n iron slab, suitably heating and cooling various parts,
r blowing it up in a wooden or iron mould.

LASS TUBING.

For the preparation of most pieces of scientific appara-
us, the glass is worked before the blow-pipe, after
onversion into tubes of varying thickness and width in
he glass works. These tubes are obtained by first

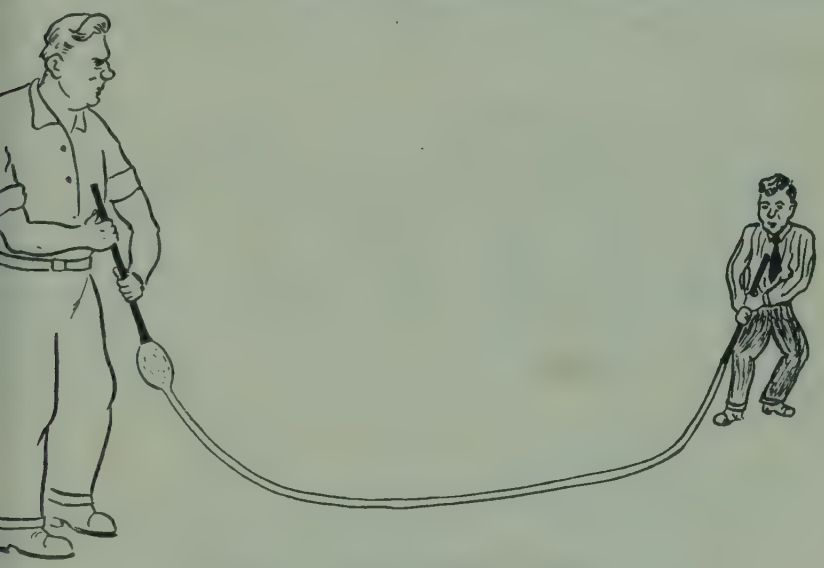


Fig. 22.—Making Glass Tubing

owing a thick bulb at the end of a glass-blower's pipe.
hen an assistant attaches a rod to a point diametrically
pposite to the blow-pipe, and the pipe and rod are
rawn apart rapidly, giving rise to a long ellipsoid of
ass, the middle of which is practically cylindrical.

Machines have been made to imitate this process, and
type in wide use is the Danner Machine which was
vented in America. Machine-made tubing is, in most
ses, superior to hand-made in general uniformity.

THE CHEMICAL REACTIONS OF GLASS.

Under normal every-day conditions, and for commo purposes, glass is considered to be a very stable sub stance. In the laboratory, however, its chemical natur gives rise to many problems, because of its reactivit with certain chemicals notably caustic alkalis. Alka silicates are dissolved by water. Glass is only slightl dissolved in water, and the manufacturers of paten laboratory glasses often publish data concerning th degree of attack by water, on their products. Acid react with the glass to a greater extent than water an alkalis attack glass to an appreciable extent.

WEATHERING OF GLASS.

This is a defect of the surface caused by advers storage conditions, particularly in very cold or, on th other hand, in steamy, atmospheres. The condensatio of moisture, particularly on soft soda glass, dissolves th alkali out of the surface. The alkaline solution is the said to dissolve carbon dioxide from the air, forming carbonate which crystallizes out on the surface of th glass.

FAULTS IN GLASS.

These are caused by:

(*a*) Small pieces of undissolved glass-making o foreign materials, which set up a strain.

(*b*) Streaks of drawn-out foreign, or imperfectl melted material which prevents annealing.

(*c*) Bubbles of gas not removed completely in th refining process. These bubbles become capil laries when the glass is drawn-out, and whe heated strongly, expand locally into bulbs spoiling the structure of the material.

SIZE OF TUBING.

The thickness of the walls of tubing is of importanc

the glass-blower. Commercially, the words thin, standard and heavy are applied to wall dimensions, and serve only as a rough indication to the worker. When ordering, it is also well to remember that diameters quoted are nearly always internal diameters measured in millimetres (except very large diameter tubes used for special work and industrial plant). Although cut into five foot lengths, tubing is sold by weight. Hence, a typical order for practise purposes might be:

5lbs. of 6–8 millimetre standard wall, soft soda glass tubing.

CERTAIN PHYSICAL CHARACTERISTICS.

An important factor in commercial glass technology is the *Thermal Endurance* of the glass. This is the least (average) temperature difference required to crack a sample of glass, and is determined by rapidly cooling a hot specimen of the glass over a known temperature range.

The Thermal Conductivity of Glass is so low that heat will not dissipate very quickly from an area to which it is applied. The glass in this area expands before the rest, and causes thereby, an unequal expansion of the whole mass, giving rise to stresses which, if large enough, cause the disruption of the material.

ANNEALING.

When glass is softened and cooled quickly the outer parts cool first, setting hard and preventing the proper contraction of the centre portion. This strain remains in the article and is only relieved by (*a*) the spontaneous cracking of the glass, or (*b*) re-heating and cooling, slowly enough to allow each part of the glass to give out its heat at the same rate. This latter process of re-heating and cooling is called Annealing.

TEMPERING OF GLASS.

It has been known for centuries that glass can be tempered and made stronger by plunging while hot into hot oil. A method which closely corresponds to the tempering of certain metals.

An interesting illustration of this is the formation of 'Rupert's Drops':

> A length of three millimetre diameter glass rod is held with the end in a brush flame of the blow-pipe. The drops of molten glass formed are allowed to fall into a dish of water. The tear-shaped drops will stand powerful blows on the bulbous part, but if the tail is chipped off, the whole drop immediately disintegrates. The particles of the disintegrated drop, when examined appear like grains of sand and can be rubbed between the hands without danger of cutting them.

The explanation of this phenomenon is, that the outer layer of glass has solidified immediately, while the interior has remained liquid. The interior of the drop then cools and contracts, but is unable to occupy a smaller volume because of its attachment to the outer layer. A strain is thus set up with the exterior of the drop in a state of compression, and the interior in a state of tension.

This principle is used in the modern tempering or toughening, of glass, and is effected by heating the sheet of glass in an electric furnace until just soft. Compressed air is then blown on to both surfaces, cooling them rapidly. A state of tension is thus set up in the interior of the glass as before, and great mechanical strength is imparted to the glass which is used for vehicle windows, oven doors, etc., etc. Like the Rupert's Drops, when broken, it disintegrates completely into small fragments which have no sharp cutting edges.

Strains set up in glass-ware due to the omission of annealing, may cause spontaneous fracture, or fracture

upon re-heating. The presence of strain is indicated by an instrument called the Polariscope (or Strain-Viewer), by means of which it is possible to view glass-ware under polarised light. One type of instrument used for this purpose comprises a polarising mirror and a Nicol prism eye-piece, fitted with a selenite plate. A strain is indicated by the formation of colour-bands. The illustration shows the structure of one type of commercial Strain-Viewer, utilising a manganese glass reflector. A more recent invention which can be used for strain-viewing, particularly in the case of laboratory glass-ware, is a laminated glass called Polaroid.

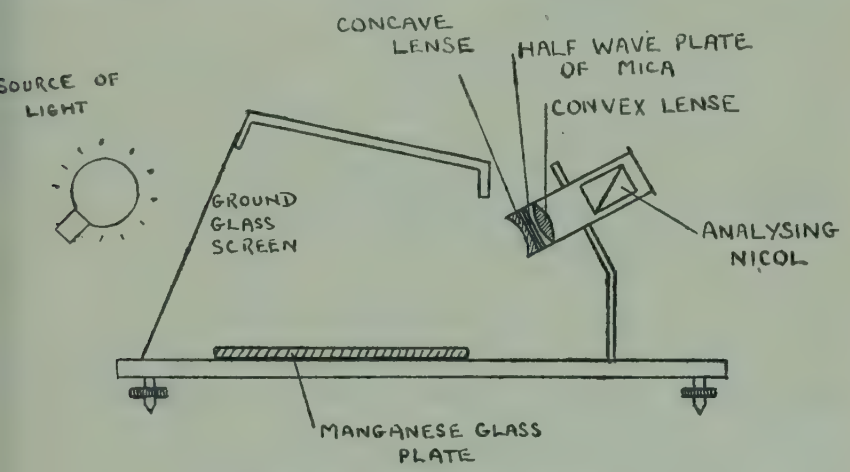


Fig. 23.—The Strain-Viewer

The intensity of the strain can be estimated qualitatively by the colour bands seen when the glass is viewed through the polariscope or Polaroid glass. Yellow indicates a maximum strain, yellow-to-red a moderate strain, and red-to-green a slight strain.

ANNEALING LABORATORY GLASS-WARE.

This is effected by re-heating the apparatus over the whole area of operation, to just below the softening

point. Strains are then released, and the glass is cooled slowly over a large luminous flame until a deposit of carbon covers the area. (See definition of Annealing.)

Although it is not always a customary practise, both Pyrex and Lead glasses must be annealed. The former glass is re-heated until nearly soft in a gas and air flame, and cooled; and the latter re-heated and cooled in a luminous flame until it is covered with a thin layer of carbon.

Vessels of fused quartz, in virtue of the low thermal expansion of the substance, do not require annealing, and can be heated to redness and quenched in cold water without cracking.

It has been found that strain is absorbed more readily by the softer glasses and metals, than by hard ones. As presently indicated, soft lead glasses are useful for making seals. When one member of a joint is in the form of thin wire, plate, or film, a greater difference in thermal expansion is allowable than when it is thick.

The following are illustrations of this:

SEALING GLASS TUBES TO COPPER TUBES.

Soft soda glass can be sealed to copper tubes by turning the end of the copper tube to a gradual taper in a lathe. The rim should be turned away to about one thousandth of an inch. Joints in glass and copper of greater diameter than fifteen millimetres should not be attempted by an amateur. Holding the copper tube in an asbestos cloth, or in tongs, heat the turned portion strongly in the blue flame of a blow-pipe. Allow it to cool. A layer of copper oxide is thus formed. Dip this oxidised portion into a strong solution of borax. Heat the end, allowing the copper borate to fuse. Soften the rim of the glass tube, which must be of such a diameter as to fit the metal taper at the point indicated in the diagram. Care being taken to ensure that the glass tube B is not in contact with the rim A, or the longitudinal

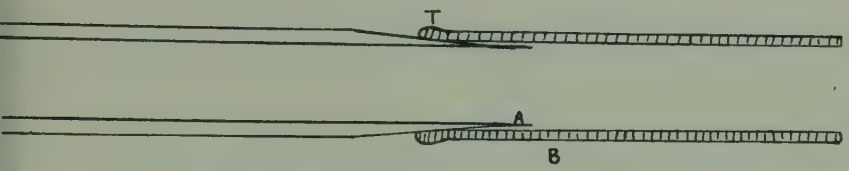


Fig. 24.—The Glass and Copper Joint

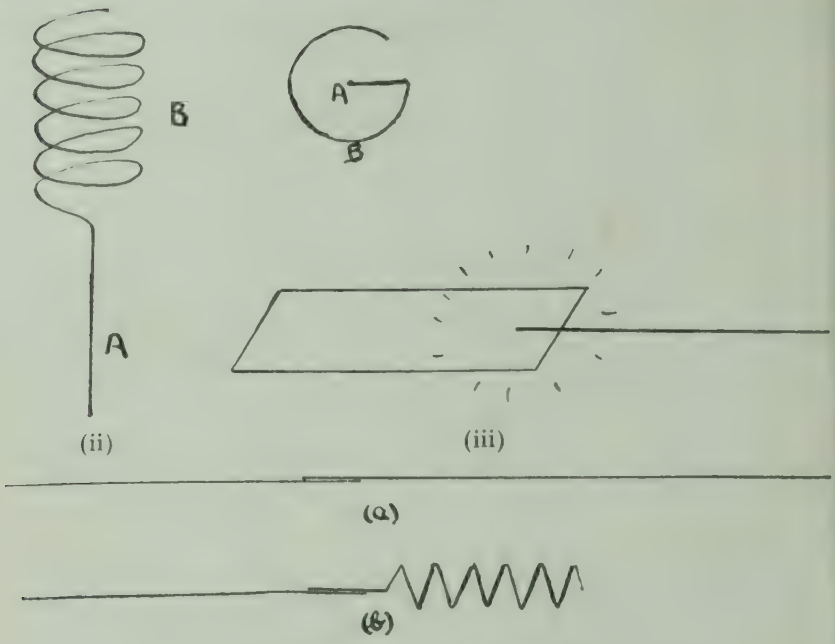
expansion would be great enough to break the joint. Fuse on with a pointed flame, thickening the glass tube a little at T, but not allowing the area of contact to be much greater than the thickening. Anneal the joint thoroughly. In this case, the strength of the glass joint must be greater than the stress produced in cooling by the disparity in the coefficients of expansion of soda glass and copper.

ELECTRODES IN GLASS.

Platinum and Soft Soda Glass Seals.—The most usual glass and metal seals in the laboratory, are those of 24 or 26 S.W.G. platinum wire and soft soda glass tubing. The joining of these materials is not attended by any great difficulty, as the respective coefficients of expansion are almost equal. To test this property, take two inches of small gauge platinum wire and a few inches of three millimetre soft glass rod. Heat the ends of both in a Bunsen flame, and when the glass is soft, push the wire into it. Remove from the flame, and pull the wire out slightly. Notice the adhesion between the glass and the wire. The glass is said to 'wet' the platinum.

Lead glass is used universally in the electric lamp industry for the conductor leads. It is found most satisfactory for sealing-in wire leads, because of its pronounced property of 'wetting' the conducting metals used.

The External Solid Seal. This is the most satisfactory method of making electrodes on apparatus, using platinum and soft soda glass.



(iv).—Preparation of Electrode

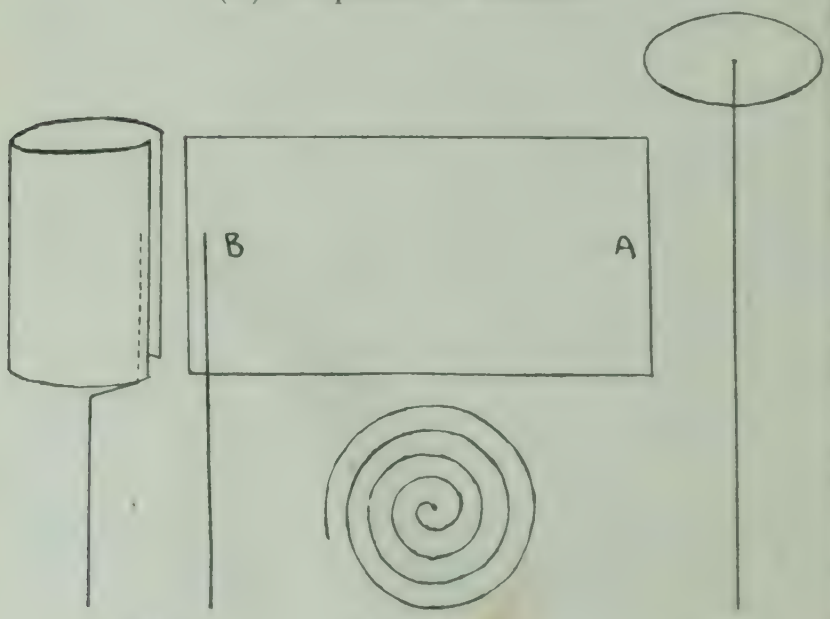


Fig. 25

(*a*) THE ELECTRODE ITSELF: For electrolytic work in general the electrode inside its tube may be:

(i) A point of wire.
(ii) A spiral of wire.
(iii) A flat sheet of foil on the end of a wire.
(iv) A corrugated sheet of foil on the end of a wire (to increase its surface area relative to the space it occupies).
(v) A coiled cylinder of foil on the end of, and in the same axis as, a wire support.
(vi) A disc on the end of a wire.

(1) This electrode needs no special preparation.

(2) The spiral electrode occupies little space, and may be wound on a pencil or a glass rod of appropriate diameter. The wire is finally bent into axial alignment with coil B.

(3) The flat sheet of foil on the end of a wire may be prepared by spot welding, i.e. placing both together and passing a momentarily heavy current through them. They can also be welded together by heating both, in position, to white heat and tapping the join with a hammer.

(4) The wire and foil are first welded together as described in (3). The foil is then corrugated in a wooden mould, or simply by using flat-nosed pliers.

(5) The foil is welded to the wire in the manner previously described, but using wide foil, and welding the wire to one side. Coil the foil starting from B. There is generally enough elasticity in the metal to prevent the coils from touching, and a great surface area can thus be obtained. A single cylinder is the most usual however.

(6) A disc of appropriate size is welded to the en of the wire.

In each of the previous cases, the wire lead to th electrode is bent into a small loop and heated in a pi point flame at this position. A bead of glass, A, from two millimetre rod of the same glass as the tube to whic the metal will be sealed, is fused on to the hot wire, a illustrated in the diagram.

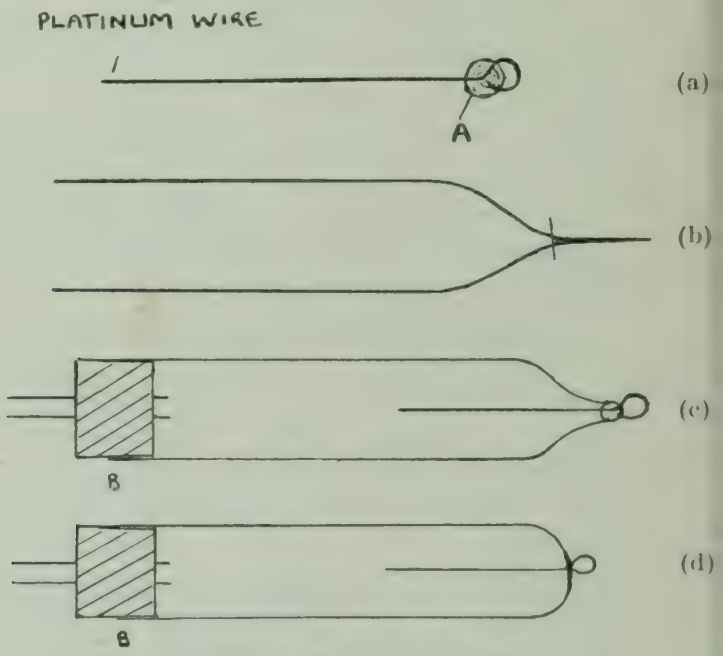


Fig. 26.—Sealing Electrode into Sleeve

(*b*) THE ELECTRODE SLEEVE: The tube into whic the electrode is to be fitted, is warmed and heated at th point required, with a pin point flame. When soft, it touched with a piece of hot glass rod, and drawn out to small cone, the tip of which is removed with a file, to a extent which will allow the bead of glass A to be a mitted. The electrode is held in position with forcep while the glass and bead are sealed together uniform

ith a pin point flame. A uniform thickness of glass at ıe joint should be achieved by careful use of the low-tube, attached at B.

HE EFFECTS OF HEAT ON GLASS TUBING.

Water vapour, carbon dioxide, and small quantities of ıe atmospheric gases, are evolved from glass when it is eated from about one hundred degrees Centigrade to s melting point. The amount of water vapour and arbon dioxide absorbed by the walls of glass tubing, nd therefore, the amount evolved on heating, increases ith the alkali content of the glass.

It is well known that a glass tube which has been vacuated appears to lose its vacuum very slightly in me, especially if it is subjected to heat. This is because ıe absorbed gases and vapour can be pumped out of the lass by lowering the pressure. Lamps and valves which re evacuated, have a substance such as metallic barium r magnesium introduced into the envelope, in order to absorb" the evolved gases.

The second important effect of heat on glass, and one hich is more obvious, is the crystallizing out of the onstituents when:

(*a*) The glass is cooled down very slowly from the molten condition, or

(*b*) It is heated until soft and maintained in that condition for a long period.

The effect of the glass becoming crystalline is well nown among scientific glass-blowers and is called Devi-rification. The phenomenon is common in inferior and ld glasses, and the substances which crystallize out in he glass are, principally, silica, calcium silicate, and evitrite. The appearance of devitrified glass is opaque, nd the surface, especially at bends where crystals have roken out, is rough to the touch. Glass of doubtful uality and age should always be discarded, as an

attempt to use such material invariably results in muc waste of time and effort.

REACTION OF GLASSES WITH THE FLAME.

Some lead glasses when worked in the blow-pip flame show a black film, due to the reduction of the lea oxide to metallic lead. This may be avoided by using hot flame, rich in air, and working the glass in the oute mantle of the flame, where atmospheric oxygen pre dominates, preventing reduction. Sulphur dioxide present in quantity in coal gas, can cause a film o sulphate on glasses. Lead glass sustains a film of lea sulphate which is difficult to remove, but the sulphat of soda formed on soda glass can, of course be rinsed o with water.

It is thought that the familiar greyish rings or 'haloe are produced by a cooling of volatilised constituents, o by a chemical action producing a sulphate vapour.

THE DIFFERENT TYPES OF GLASS USED IN LABORATORY GLASS-BLOWING.

1. Soft Soda Glass.
   - (*a*) Melts easily in a Bunsen flame. Range 450° 500°C.
   - (*b*) Quite cheap and readily obtainable in an size and quantity (about 1/3 per lb.).
   - (*c*) Needs careful heating and annealing.
   - (*d*) Prone to devitrification.

This glass should always be the first used for practice i glass-blowing.

2. Pyrex (the trade name of a patented boro-silicat glass).
   - (*a*) Hard, colourless glass with a low coefficien of expansion. Only small gauge tubing ca be softened in a hot blow-pipe flame. Soften

ing range 600°–800° C. Oxy-gas flame is required to work it.

(*b*) It is more expensive than soda glass.

(*c*) It can be put directly into a flame. Only requires annealing, and that to a much lesser extent than soda glass. Annealing is effected by heating the apparatus in a coal gas and air flame until it is almost at the softening point then allowing it to cool.

(*d*) It is not prone to devitrification.

ts low coefficient of expansion enables the worker to eal up cracks without further spreading them. Pyrex lass should only be used when the worker has had a ood deal of practice with the other types of glass.

3. Monax (and the American Nonex). (Trade names f patented boro-silicate glasses.) This type of glass ontains zinc, is harder than soda glass, and is colourless.

(*a*) Ordinary glass-blowing with this glass can be carried out on the gas and air blow-pipe, although the softening temperature is quoted as 700°C.

(*b*) It is more expensive than Pyrex.

(*c*) It can be heated up at a faster rate than soda glass, but requires annealing, although not as thoroughly as soda glass.

(*d*) It is not prone to devitrification.

This glass, like Pyrex, should only be used after some experience has been gained with soft soda glass.

4. Hysil (the trade name of a patented boro-silicate glass). It is hard, strong, and colourless, containing Aluminium.

(*a*) Small gauge tubing can be worked in a gas and air flame. Larger material, and joints, require the addition of oxygen to the flame.

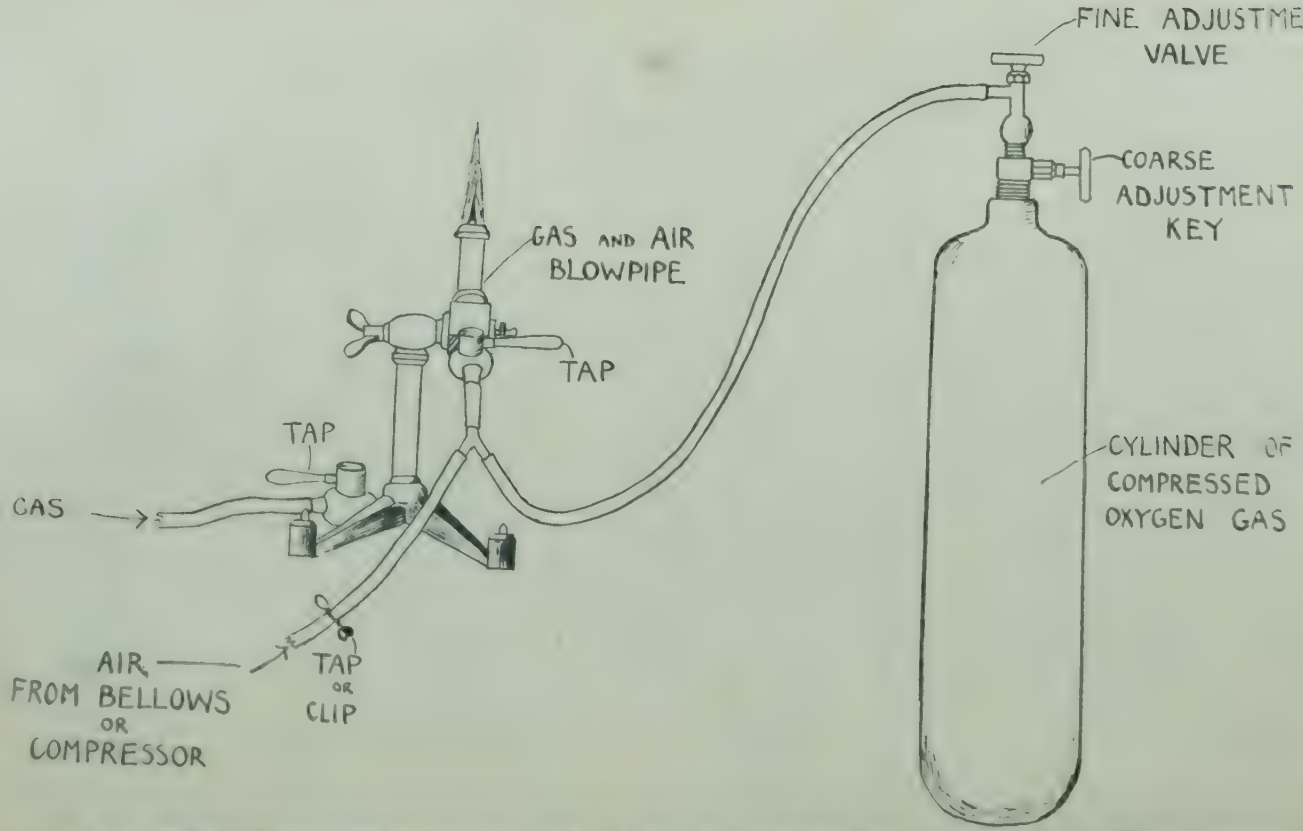


Fig. 27.—The Introduction of Oxygen to Gas and Air Burners for the Working of Pyrex, Hysil and Monax.

The softening range being similar to that of Pyrex.

(*b*) The price is similar to that of Pyrex.

(*c*) It can be heated up rapidly; but it must be annealed, as in the case of Pyrex and Monax.

(*d*) It is not prone to devitrification.

The qualities of the different glasses can best be appreciated by working samples of each in the flame.

THE INTRODUCTION OF OXYGEN TO THE BLOW-PIPE FLAME

[*See Diagram Facing*]

It will be seen from the diagram, that the oxygen supply can be diluted at will, by the attachment of a "Y" piece, one limb of which is connected to a supply of air from a bellows or a compressor.

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CHAPTER IV

BENDING, JOINING, SEALING OF TUBES AND BULB-BLOWING

Bending.

1. *Right-angle bend.*

In order to achieve this, it is necessary to heat and soften a length of tubing at least three times its diameter, and to gently urge the tube into shape. The tube must

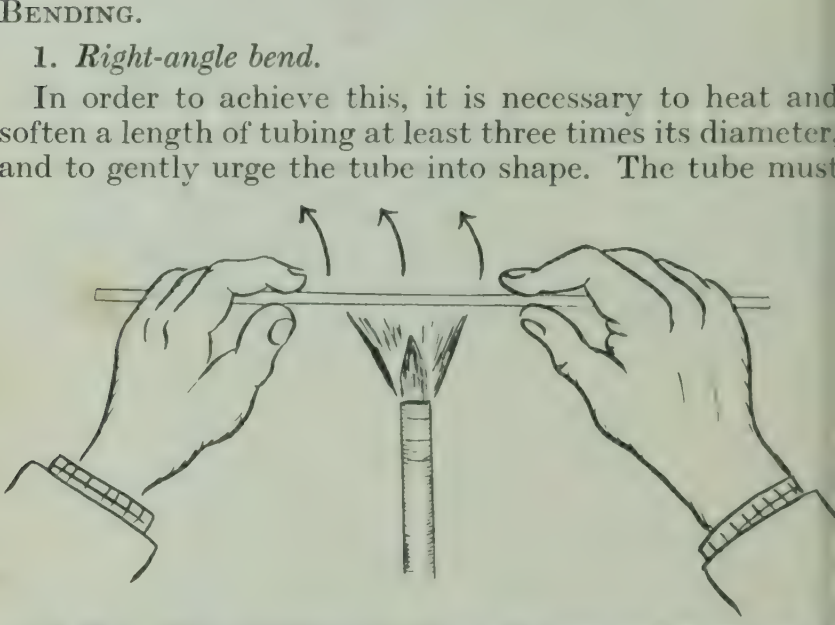


Fig. 28 (i).—The Position of the Hands for Bending Glass Tubing

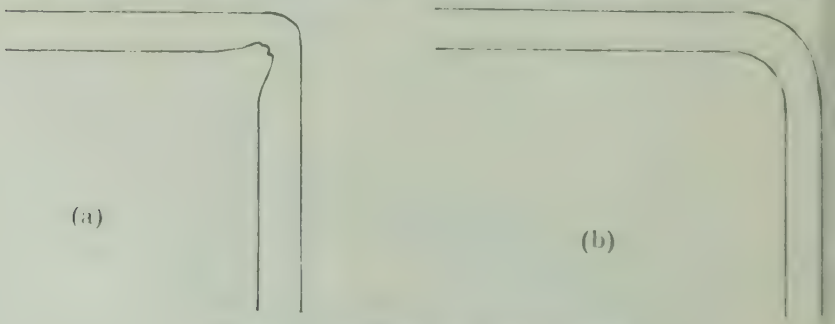


Fig. 28 (ii).—Bending Glass Tubing

ot be over-heated, nor must it be forced vigorously to position. In heating, it must be continuously tated, using for this purpose the thumb and first ger of each hand. Neglect of any, or all, of these ecautions usually results in a poor bend, with a buckled all on the inside of the angle, as in (*a*) of Fig. 28. After good deal of practice with standard walled six millietre diameter tubing, the bend should be uniform, as (*b*).

The operation should be done slowly, and as many nds as possible made on a foot length of tube each me, for economy.

2. *A 'U' Bend.*

(*a*) A length of tube, equal to six or seven times its diameter, should be heated in a batswing flame, rotating carefully.

(*b*) In the case of a large thin-walled tube, the heating is continued whilst the tube is very gently pressed inwards from the ends, towards the hot portion. This causes a thickness of glass to form which allows the tube to be bent and pulled apart slightly. While doing this, the tube is blown out with puffs of air to its original diameter.

(*c*) With a small diameter tube, the same length should be subjected to heat, and the tube gently urged into a 'U' shape when just soft. Care must be taken in both this and the latter case to avoid twisting the tube. The tube limbs should be compared for alignment with each other, continually.

A passage on the bending of tubes usually contains a escription of spiral tube making. It is now considered, owever, that freehand spiral winding is of such diffiulty, as to occupy an excessive amount of the student's

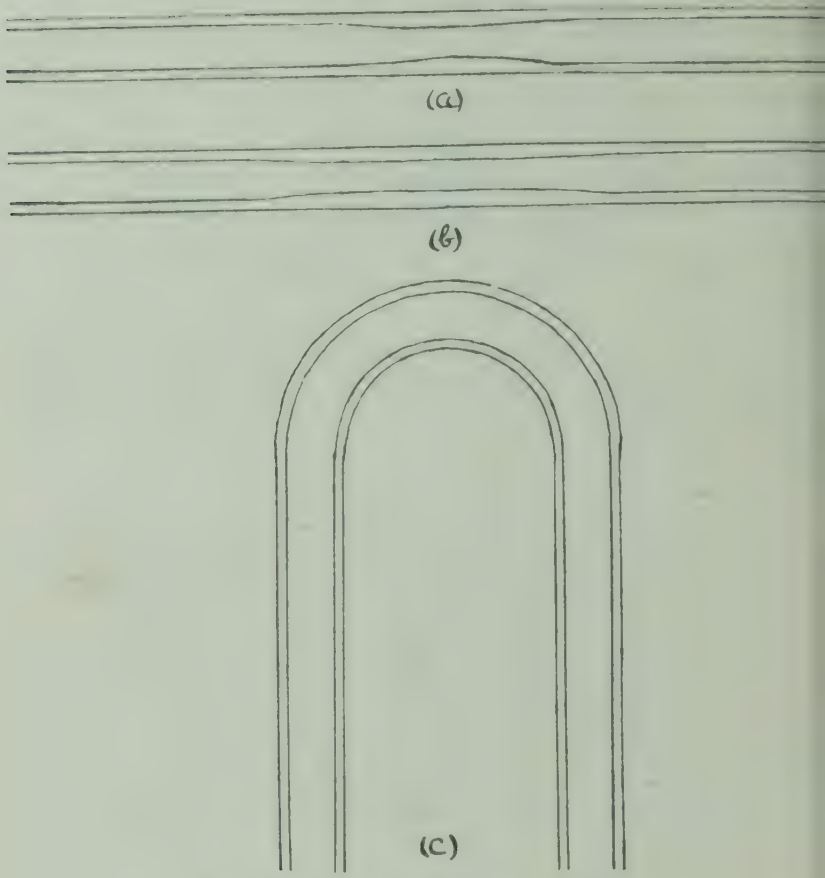


Fig. 29.—Stages in Making a 'U' Bend

time in proportion to its usefulness, and relative to th time required to familiarise the student with oth preliminary technique.

3. *The Bending of Wide Tubing.*

This is effected by heating the tube without rotatio in the batswing flame. One end of the tube is block with a cork, and the other fitted for blowing, either with bored cork and blow-tube, or, if the diameter is moderat merely by fire-polishing for mouth-blowing.

The heating is commenced gradually and increased ntil the tube softens. A length several times the iameter should be heated as with ordinary tubing and, s the 'inside' of the bend collapses, it should be blown ut again to its original diameter.

'U' bends in wide tubes are accomplished in much the ame fashion as with small gauge tubes, except for the lowing out of collapsed portions as they occur.

Tubes of diameter greater than two inches are usually ormed into a 'U' in two steps, two right-angle bends eing formed separately, the first being cooled before ommencing the second.

OINING TUBES.

Take a fifteen centimetre length of six millimetre iameter glass tube. Cut it in the middle, as described n the previous chapter, using a file. Now the aim in ube-joining is to connect these two pieces so that the oin is almost imperceptible. This ideal is, in normal ircumstances, seldom attained by amateurs, as the join s not always in such a convenient position.

Difficulties usually experienced:

(*a*) the two pieces of glass to be joined may not be be of the same quality;
(*b*) the two pieces may not be of the same diameter;
(*c*) the walls of the two tubes may not be of the same thickness.

Warm the cut ends of the tube, and heat in a small wo-inch) blue, pointed flame of the blow-pipe. Rotate etween the fingers of each hand continuously, until the nds become soft. They should not be heated too much, ausing deformation. At this point place the ends quarely together. Cool in a smoky flame (no air), and ipe free of carbon when cold. Examine the joint, see it leaks. Test it for strength; it will probably snap asily.

Repeat the process with one end of the tube stoppere and the blow-tube attached to the other end. Place th mouth-piece in the mouth and when the tube has bee squarely joined as before, blow gently, from the check and not the lungs, until the joint assumes the smoot bulbous shape as in diagram. Continue to work this i the flame until the bulb diminishes, thickening th portion of the tube in so doing. Draw-out the tub gently while continuing to heat it uniformly, until th

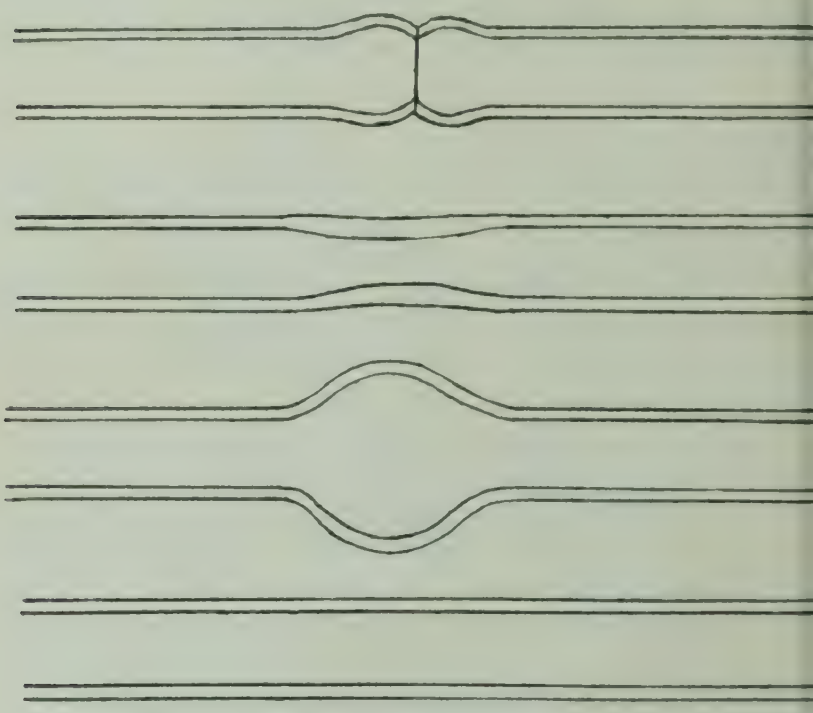


Fig. 30.—Joining Tubes

thickness of the wall is uniform, and the diameter equ to that of the rest of the tube. This is the method joining all tubes.

If, as previously suggested, the tubes may not be

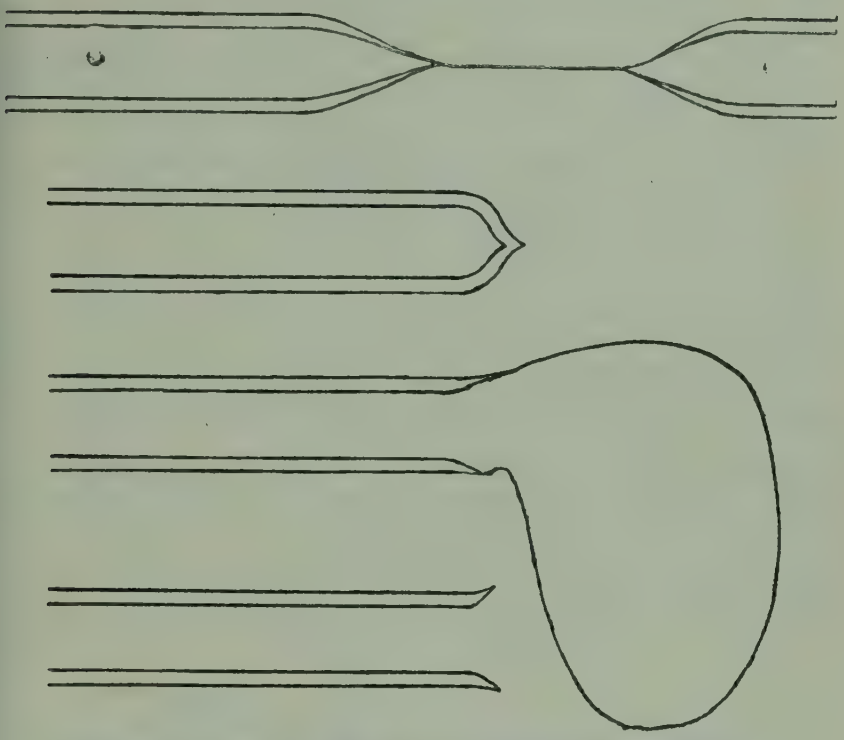


Fig. 31.—Drawing-off and Blowing-out as an alternative to Cutting Glass Tubing [See also Figs. 17 and 18]

the same quality glass, some difficulty may be experienced with disparity in melting points. When such tubes are partially fused together they must be heated sufficiently to allow the glasses to flow into each other as far as possible without deforming the tube.

The tubes to be joined, instead of being cut, can be drawn-off as in Fig. 31, the end sealed, heated uniformly and blown out completely as previously described. The adhering film of glass is brushed away, and the tube left open as indicated. It can then be joined as before.

Tubes of unequal diameter are joined as follows:

Method I.—The wider tube is drawn-off forming a thick walled spindle (Fig. 32). The constriction is cut off

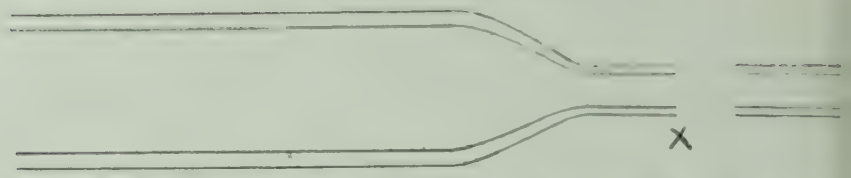


Fig. 32.—Joining Tubes of Unequal Diameter. Method I

squarely at (x) where the diameter closely approximates that of the tube to be joined on to it. Skill in drawing-off the wide tube so that the walls at (x) are uniform with that of the tube to be joined on, is only acquired after practice. The tubes are then joined in the usual way.

Method II.—The larger tube is drawn-off and sealed at the end; it is heated and blown, holding in a vertical position for this purpose, until the end is hemispherical. The blow-pipe is then adjusted to give a small, pointed flame which is played on the centre of the end, before

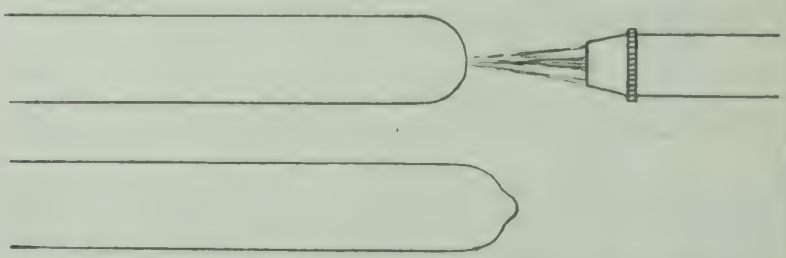


Fig. 33.—Joining Tubes of Unequal Diameter. Method II

the glass cools down (See Fig. 33). When soft, this area, of about five millimetres diameter or according to the size of the tube to be joined, is blown out to a hemisphere.

This is again heated and blown out completely, the pieces of glass film being brushed away with a file. The narrow tube, and this prepared end are held within a short distance of each other in a blue, pointed flame until the glass softens. The joint is then made as previously described.

JOINING CAPILLARY TUBES.

In this case the ends of the tubes should be sealed off and small bulbs blown, as shown in the diagrams. The ends are then cut off the bulbs with the aid of a file and the red-hot drawn-off tip of a glass rod.

The prepared ends of the tubes are placed together as indicated in the diagram, and the joint made as in the case of standard wall tubing.

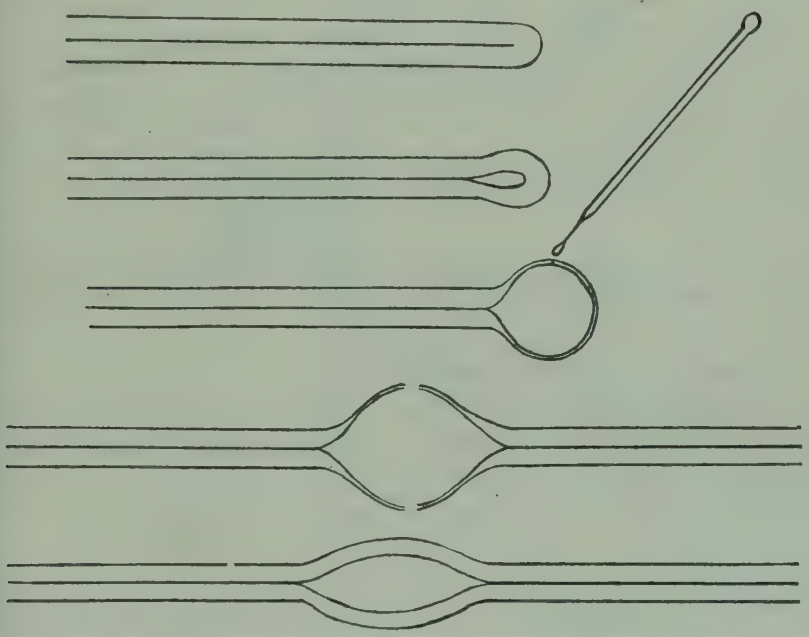


Fig. 34.—Preliminary Stages in Joining Capillary Tubes

The beginner will have some difficulty in keeping open the bore of a very narrow capillary tube, when thickening and pulling the joint. Joints in material such as thermometer tubing, which is sometimes of extremely fine bore are so rarely required that the beginner need waste no time in attempting them.

In most cases of joining one capillary tube to another, an increase in the bore at the joint can be allowed for.

CONDENSATION OF MOISTURE FROM THE BREATH.

When blowing out joints, etc., with the use of the rubber tube and mouth-piece, moisture from the breath condenses on the cooler parts of the tubes, and with the

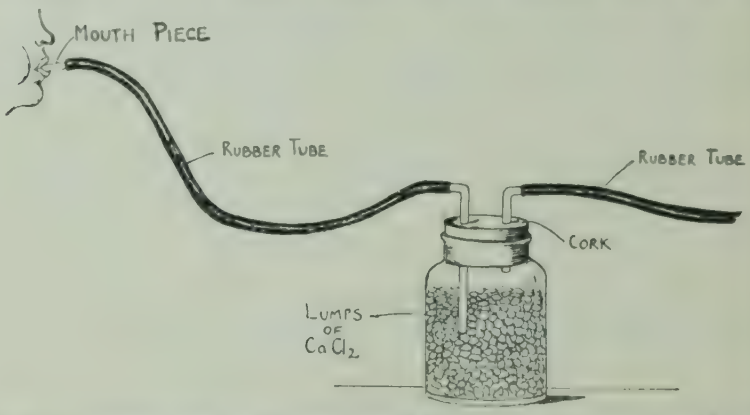


Fig. 35.—Apparatus for Prevention of Moisture Condensation during Glass-Blowing

movement of the apparatus is likely to run on to the hot parts of the glass and crack them. This may be prevented by interposing a bottle containing fused calcium chloride, between the mouth-piece and the apparatus.

SUPPORT OF TUBES WHEN JOINING.

[Using the repair of the burette as an example]. Occasionally, burette taps are broken off the stem of the tube, or the plug is lost or broken. In the former case, a new tap can easily be fused on, and in the latter case, the remaining socket should be cut off and a new tap put on, rather than an odd plug sought for, as this is seldom if ever satisfactory.

The stem of the burette is unwieldy and long, and is best supported in a position in which it would normally be held with the hand. A number of blocks of wood with 'V' shaped cuts made in the top, are most useful for

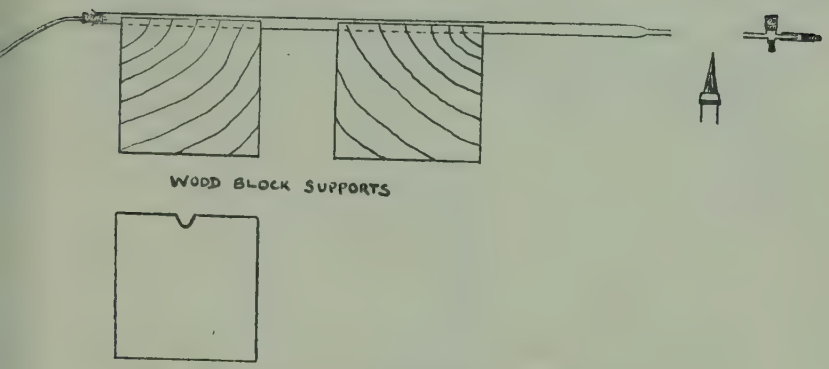


Fig. 36.—Support of Tubes while Joining

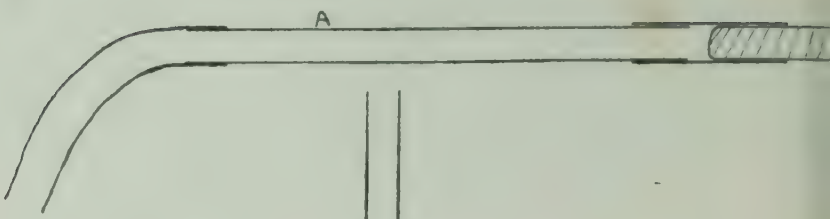
his purpose. They are arranged as in the diagram, upporting the tube, whilst the tap is held in the right and, the plug having been removed, and corks placed n the holes of the socket.

The join is then made in the usual way, care being aken not to allow the stem of the burette to become too arm as, on cooling, it does not contract to its original ze for many years. In the case of school burettes, this robably does not matter very much, (they may even ave been previously expanded by washing in warm tap ater). In the case of a burette certified by the National hysical Laboratory, great care must be taken not to eat the graduated portion of the tube to any degree at ll.

ONSTRUCTION OF 'T' PIECES.

For practising this, eight millimetre diameter tubing ith walls of $1\frac{1}{2}$ to 2 millimetre thickness should be used. ake a twenty centimetre length of this tubing and cut into two ten centimetre pieces, with a clean square le-cut.

Method.—Fire-polish the ends of a tube, A, and one nd of another, B, by rotating the tip in the hot region of ne blow-pipe flame. To the tube with both ends olished, attach the blow-tube, and to the other end, a



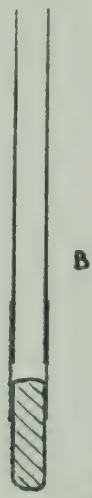


Fig. 37 (*a*)

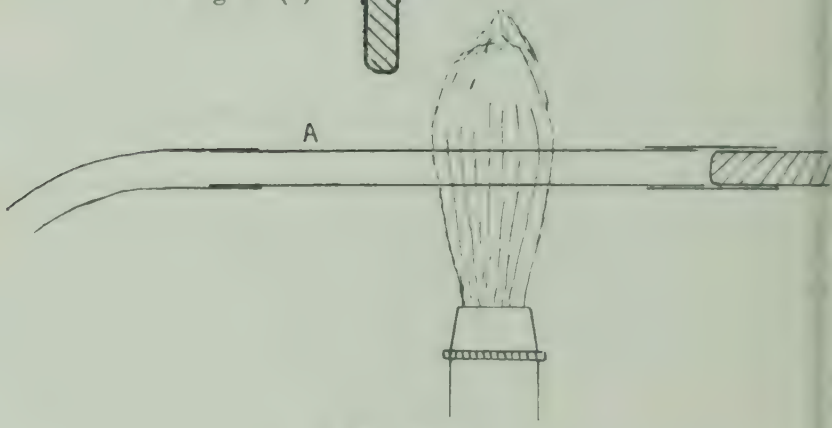


Fig. 37 (*b*)

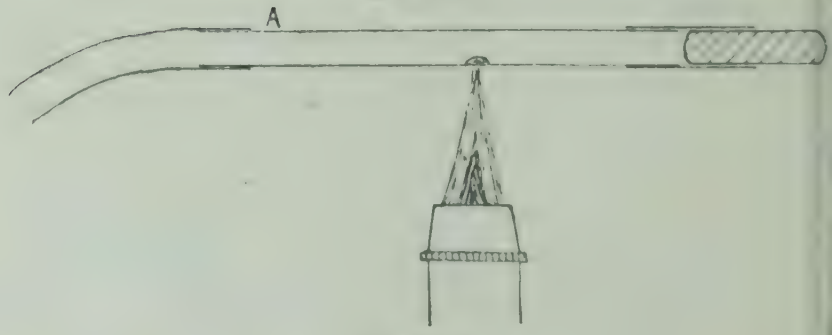


Fig 37 (*c*)

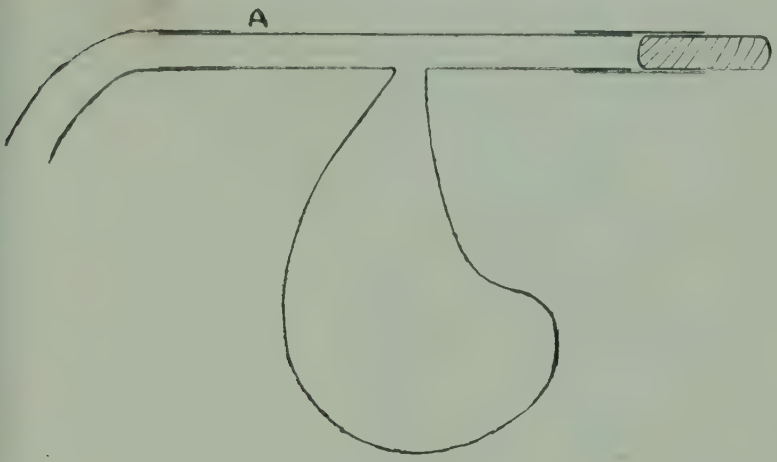


Fig. 37 (*d*)

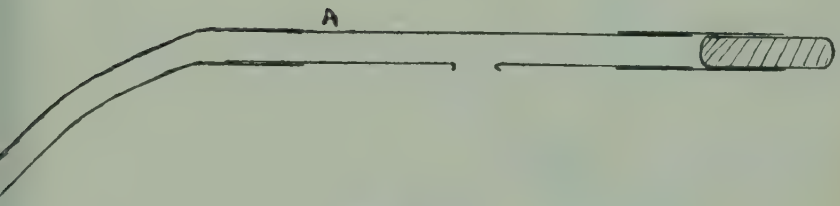


Fig. 37 (*e*)

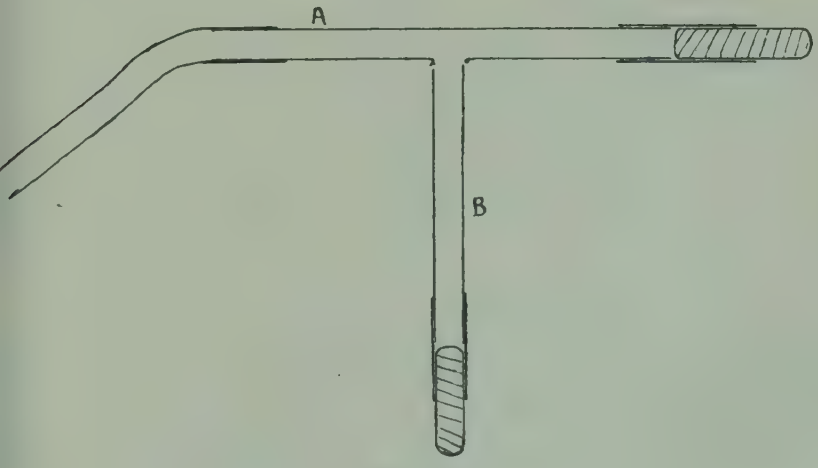


Fig. 37 (*f*)

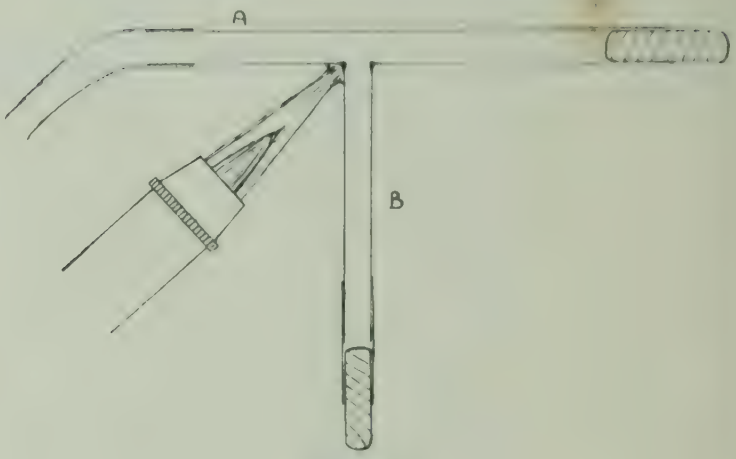


Fig. 37 (*g*)

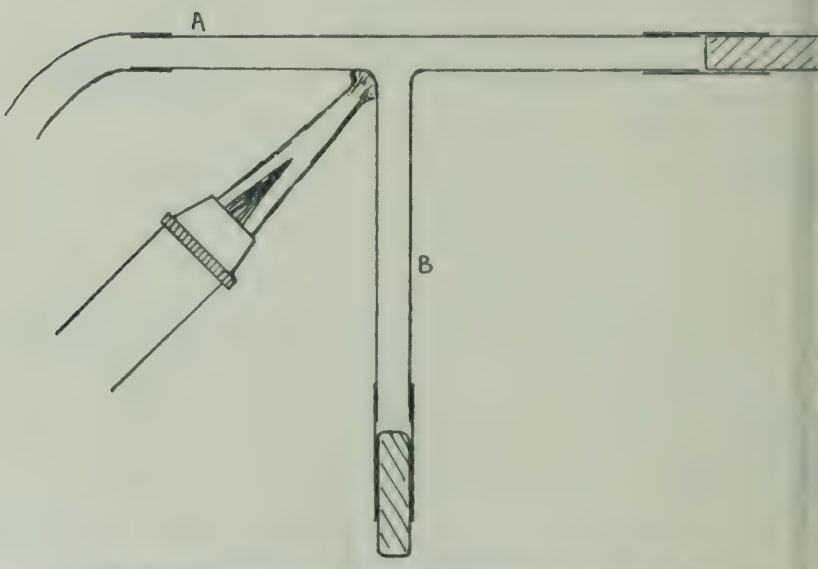


Fig. 37 (*h*).—Stages in the Construction of the 'T' Joint

glass and rubber plug. On the fire-polished end of th other tube place a plug.

Blowing a hole in a tube: Take hold of A in bot hands, and gently warm the centre portion in the blow

ipe flame. Place the mouthpiece of the blow-tube in the nouth, lower the blow-pipe flame quickly, until it is bout 1½ inches long, blue, and finely pointed. Taking are not to deform the tube, heat an area about five nillimetres in diameter until soft enough to suck the lass in and out gently (using the cheeks). Take the ube from the flame and blow strongly. Brush away the idney-shaped bubble of glass, and fire-polish the hole.

In an effective join, this hole must closely approximate o that of the diameter of the tube B, to be joined to it. Ieat the rim of the hole in A uniformly, at the same me heating the end of the tube B. When both are in fluid condition, place them gently together. A soft uff of air meeting with resistance, and causing no jets f air from the joint, is a sufficient sign for the finishing f the joint.

Holding the 'T' piece in the position relative to the ame shown in Figure 37, allow the glass to become uid, so that the joint can "run" into a smooth curve all ound, being supported and prevented from collapsing y a gentle pressure from the cheeks. An important eature is to see that the thickness of the glass at the oint is the same as that of the tubes. Admit a little nore gas to the flame and round off the joint by heating nd blowing uniformly, until it appears as in Figure (*h*).

Finally, admit more gas and cut off all the air, giving smoky flame. With this flame make any necessary djustments such as making the angle between the mbs 90°, and aligning the tube, B, with A. Then nneal carefully until the joint is covered with soot. As large proportion of lampwork involves making joints, he 'T' piece is an important feature of the preliminary ractice. Draw-off the end of limb B and make another oint on the opposite side of the tube, about half an inch way from the original joint. If the original joint was ot annealed properly, it will now crack. Repeat this, sing another twenty centimetre length of tube, until

you have made about twelve joints, using tubing up to twelve millimetres in diameter.

FILLINGS.

If, when making joints, a fissure appears, it will be noticed that, because of the surface tension of the glass, further heating tends to rapidly widen the hole. In any case like this, a number of drawn-off spindles of two millimetre diameter glass rod, of the same quality glass as that of the tubing, should be at hand. Two or three inches is a useful length. On the appearance of the hole

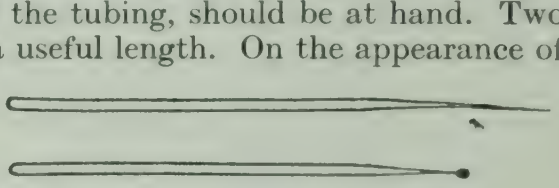


Fig. 38.—Drawn-off Rod for Filling

in the apparatus, the drawn-off point of a spindle is heated, and the little red-hot blob of glass so formed introduced quickly into the hole. The introduction of a quantity of glass should be avoided, as this will thicken that side of the wall, and spoil the joint. On sealing the joint, the heating should be such as to allow the glass to flow smoothly until the thickness is uniform.

INTERNAL JOINTS.

This type of joint is similar to that of the joining of a wide tube with a small diameter tube, except that the small tube passes some distance into the large tube. The joint is generally made with the inner tube supported, but in simple cases, unsupported.

Method I.—The large tube is sealed off, and a hole of required diameter blown in the rounded end, just as in the joining of the tubes of unequal diameter, described previously. The smaller tube is heated, and a small bulb produced at the point required for the fusion by pressing the tube inwards and gently blowing as the glass becomes fluid. The hole in the larger tube and the

bulb just prepared are warmed and fitted together. The glass is not fluid enough for cohesion to take place.

Adjust the gas and air of the blow-pipe to give a fine pointed flame, and seal the joint carefully all round, blowing through A; B being sealed with a cork. When a smooth joint is obtained, the bulb C is carefully heated

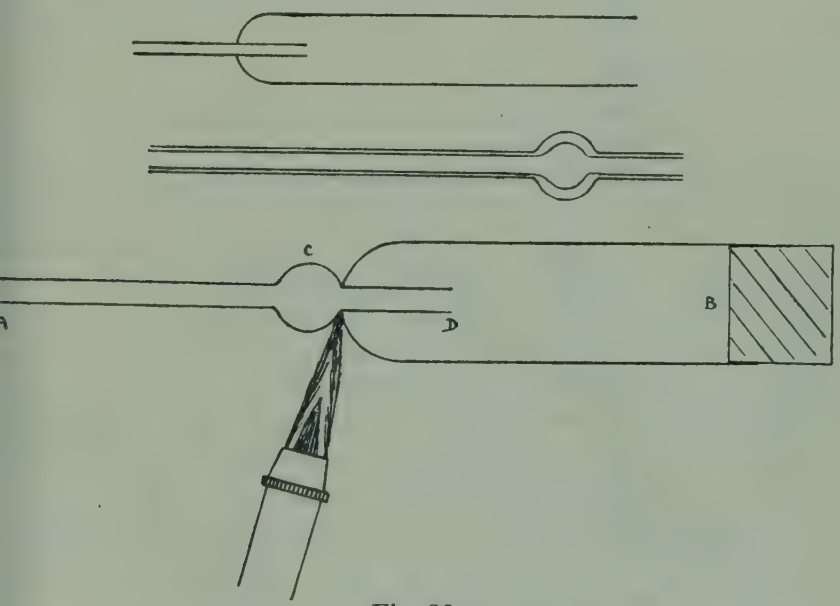


Fig. 39.—
Preparation of the Internal Joint. Above: The Completed Join

and drawn out. Parts D and A of the narrow tube may now be brought into alignment by gentle heating at the joint with a smoky flame. On completion, the joint must be thoroughly annealed by heating in a luminous flame, until an even layer of carbon is deposited on the apparatus.

Method II.

(*a*) If the inner tube D is too heavy to be dealt with without deformation, it is supported by means of a cork, or plug of fibre. The making of a sealed water jacket for a small Liebig condenser is an example of this.

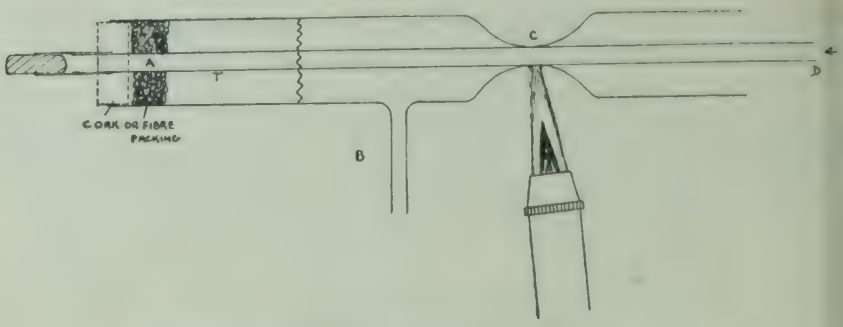


Fig. 40.—Internal Joining by Method II (*a*)

A loosely fitting cork is bored to fit the tube T at A. The other end of T, passing through the drawn-out 'waist' of the large tube, allows air to be blown in through D. A short, right-angled joint of small gauge tubing, later for the admission of water, allows air to be blown into the annular space between the tubes. The joint at C is made by uniform heating and careful annealing. Much care must be exercised in the removal of the cork from A. The tube T must be supported while it is being eased out of position. Accurate boring of the cork, in the first place, will save much time at this stage.

(*b*) If the narrow tube ends within the wide tubing, it can readily be supported by a piece of glass rod.

INTERNAL 'T' JOINT. [Fig. 42]

A very useful joint, and one which at first sight appears really difficult, is the joint in which the double limb of the T is enclosed. The operations are as follows:

1. Blow out a hole of suitable size in tube A in the required position, and fire-polish.
2. Prepare 'T' tube BD and fix in position with corks.
3. Prepare tube C of the same diameter as BD.
4. The hole in the wide tube is then heated with a small brush flame, the flame is adjusted to a smaller pointed type, and the circumference of the hole,

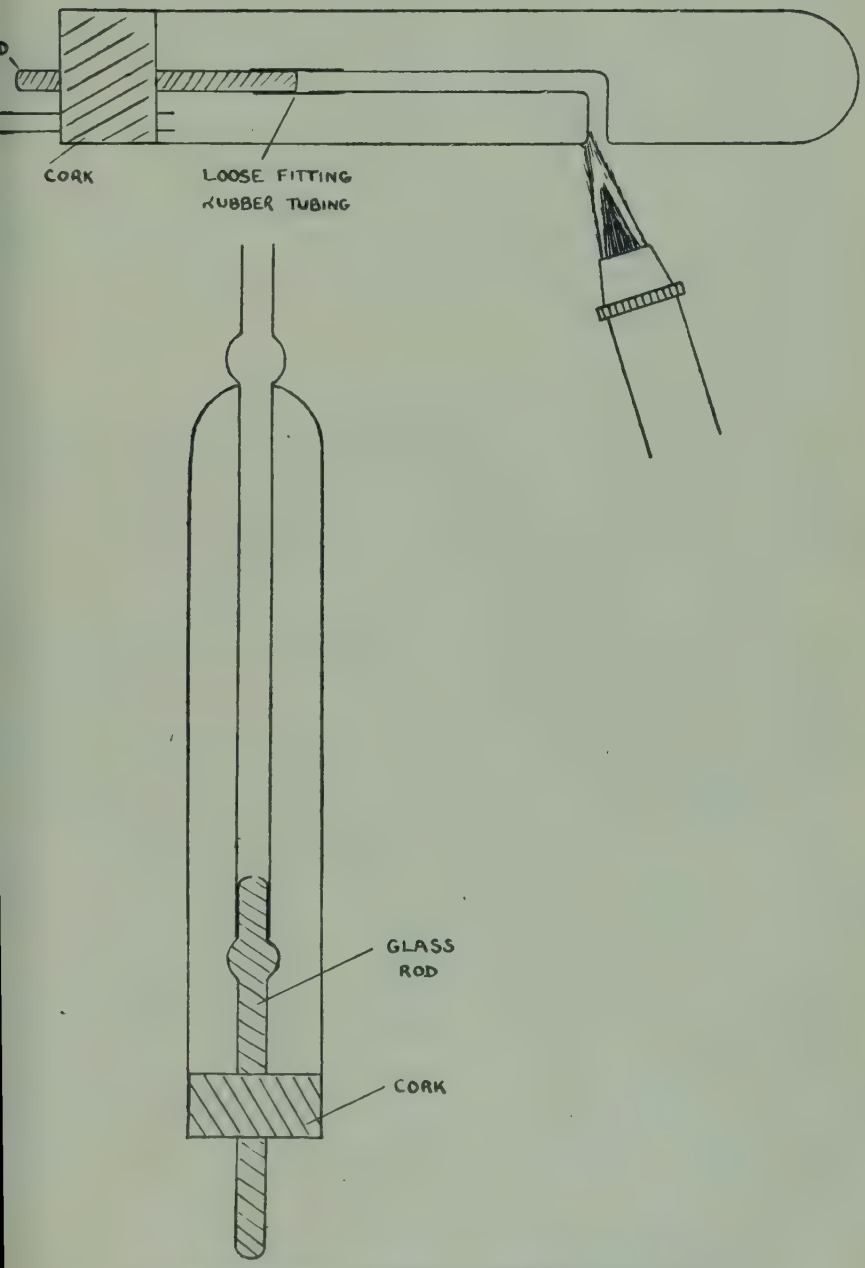


Fig. 41.—Internal Joining by Method II (*b*)

and the side tube C are heated more strongly. The tubes are placed squarely in contact when the glass has been softened.

5. By careful blowing through C and E and heating uniformly, the joint is shaped and finished.
6. It must then be well annealed by heating up the whole joint and cooling, using a luminous flame, until a layer of carbon has been deposited over the worked parts.

THE CLOSED DOUBLE JOINT.

This joint, familiar in the Soxhlet extractor, is made in two separate parts, the limbs of which are then sealed together. Practice in this joint should be carried out with a twenty-four millimetre diameter tube, and two six to eight millimetre diameter tubes.

Method.—The joints of the narrow diameter tubes to the large diameter tube, should be made in the customary way, and in the required position, as for example in Fig. 44. Tube E should be shorter than F for economy. Cut off tube E with a file, to within $\frac{3}{4}''$ of the tube D. Now measure the exact length of F required to bend it to meet the tube E, as in Fig. 45. By the natural elasticity of the glass, F can be gently pulled apart from E. The ends, heated in a pointed flame, are allowed to spring together when soft, and are worked to a smooth joint by the use of a blow-tube connected at G. Both joints at E and H must be re-heated at the completion of the work and allowed to cool in a luminous flame until coated with carbon.

All other joints, even in the construction of the most complicated apparatus, are modifications of these examples.

SEALING TUBES.

In closing the end of a tube, the result should be a

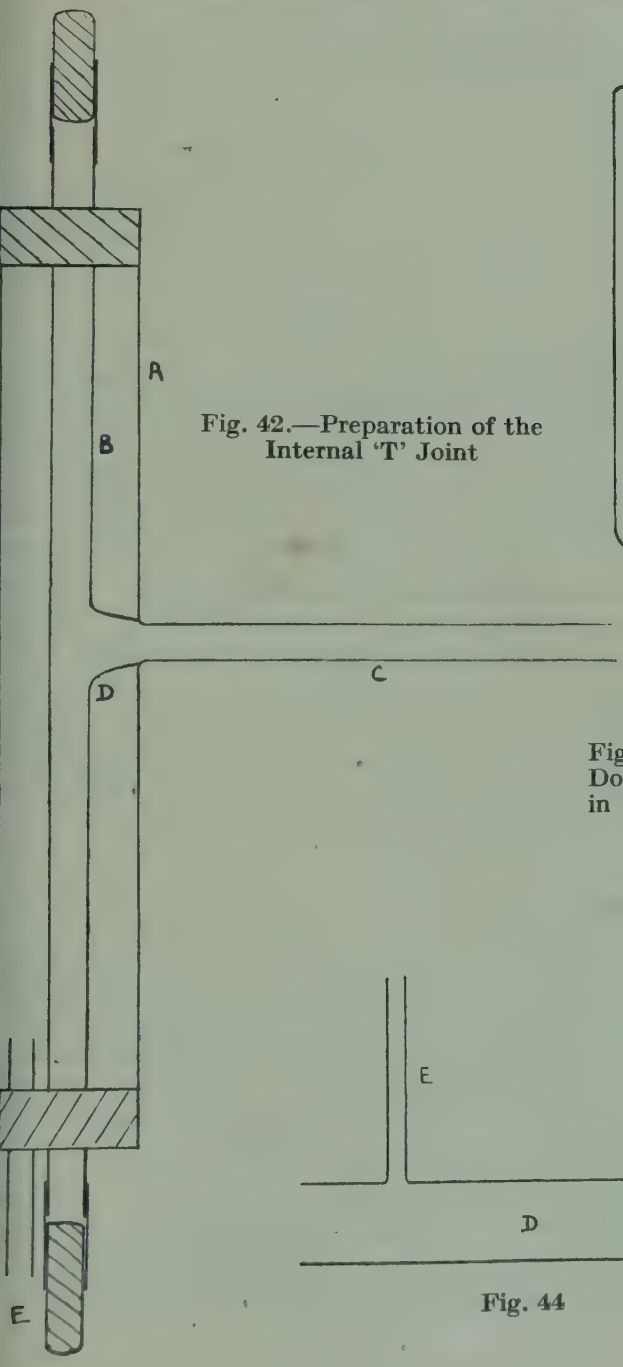


Fig. 42.—Preparation of the Internal 'T' Joint

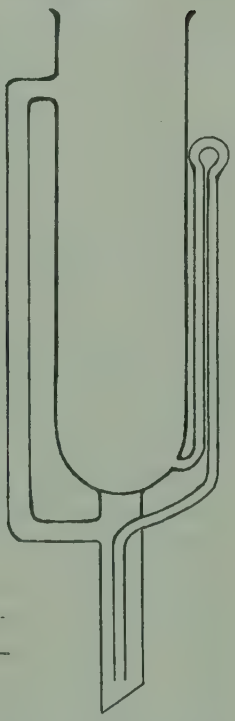


Fig. 43.—The Closed Double Joint shown in the Soxhlet Extractor

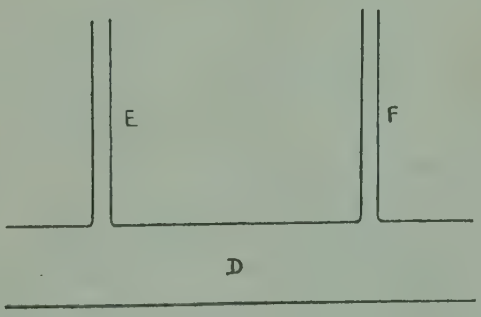


Fig. 44

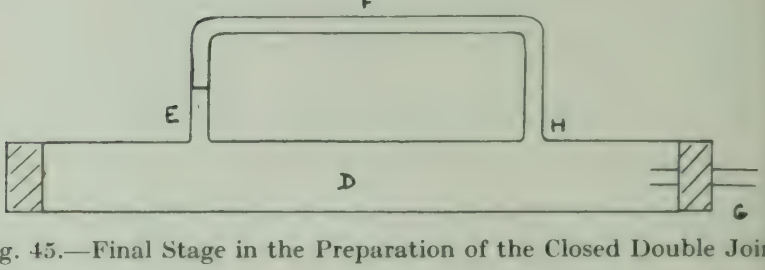


Fig. 45.—Final Stage in the Preparation of the Closed Double Joint

perfect hemisphere of glass of the same thickness as the rest of the tube. This is important, not from the decorative point of view, but from the fact that the strength of the end of the tube is then at its maximum. It is thus important in the sealing of tubes for use on high or low pressure apparatus. The result of evacuating a flat bottomed flask on a pump, will provide all the evidence required of lack of structural strength of such an irregular shape. This experiment can be performed effectively with a spherical bulb, blown in eight millimetre soda glass tubing, and a similar bulb with the end flattened by pressing while hot on to an asbestos sheet. When exhausted with a vacuum pump, the latter collapses with a sharp report. Both should be about four centimetres in diameter and wrapped in a duster.

METHOD OF SEALING TUBES.

The tube is heated in the region of A, as in Figure 46, and the spindle B drawn-off, as in the diagram. Using the large bore jet of the blow-pipe, heat the sealed end of the tube with a moderate brush flame, rotating continuously. The slight thickening of glass at the end of the seal is then removed with a hot glass rod, which adheres to the bead at the end of the tube, and when twisted between the fingers, winds off a thread of glass from this thickening. Any remaining thickness is removed by heating it in a brush flame and blowing out. When the end of the tube is of uniform wall thickness

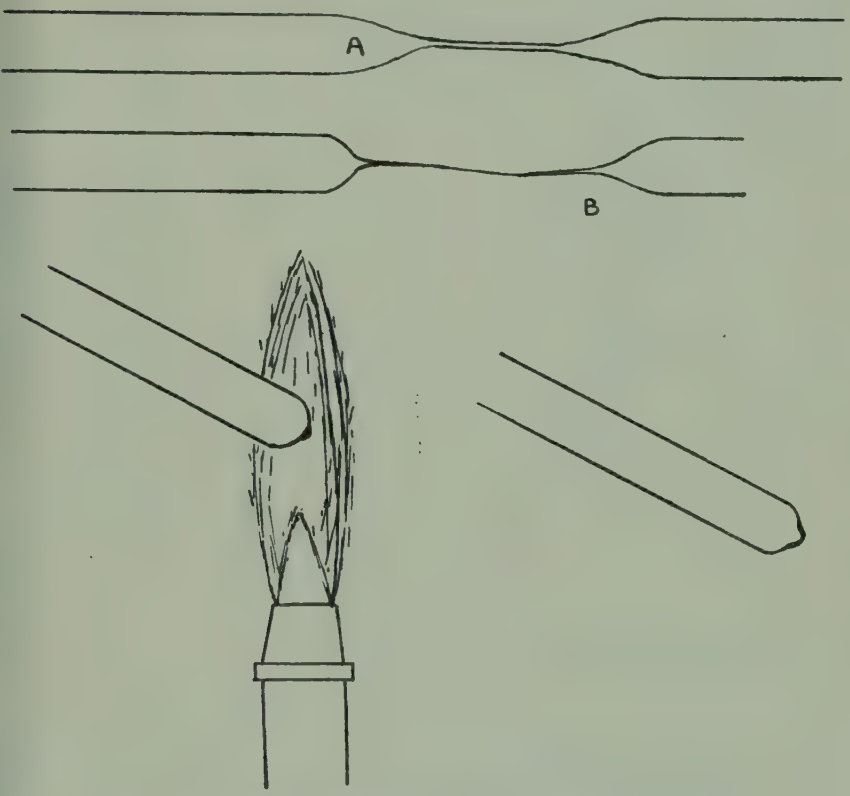


Fig. 46.—Preliminary Stages in Sealing Glass Tubing

t is heated carefully and gently blown out into a hemisphere.

BULB BLOWING.

For practice, six to eight millimetre diameter tubing should be used.

Method A.

(i) Draw-off the end of the tube and seal it hemispherically, as previously described. (Fire-polish the opposite end.)

(ii) Continue to heat in a brush flame, rotating, until a thickening of glass is accumulated in the

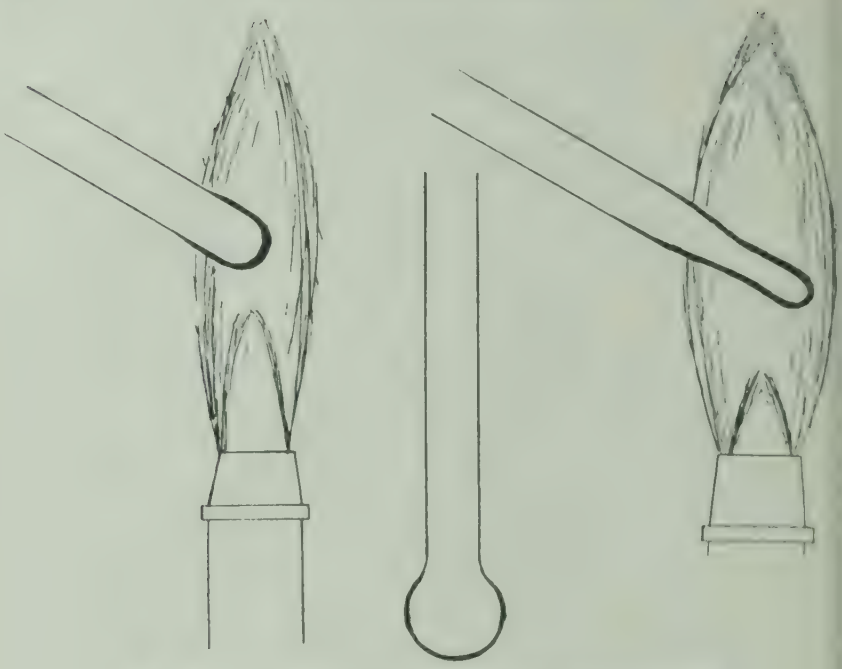


Fig. 47.—The Preliminary Stages in Bulb-Blowing

walls of the hemisphere. This thickening must not be at the tip of the tube, and in order to avoid this, the tube should be rotated at about 30° from the horizontal in the flame.

(iii) Continuing to rotate the tube, remove quickly from the flame, and with the bulb hanging vertically downwards give one or two gentle puffs from the cheeks, until the end of the tube has increased in size about half its diameter.

(iv) Continue to heat and rotate in the flame, until the bulb and a little of the tube above it, collapse slightly. Blow up again, this time to the required size, rotating once at each puff of air. Annealing is not necessary. Break off the bulb with a few sharp blows of a file. Heat strongly in a fierce flame and draw-off the ragged end

with a two millimetre glass rod. Seal hemispherically and begin again.

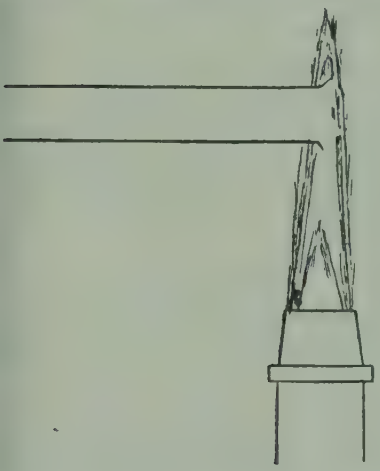
Blow three or four bulbs during each practice period.

The great secrets of bulb-blowing practice are:

1. Heat uniformly.
2. Start by blowing small bulbs. (The beginner invariably wants to see a four-inch globe appear on the end of his tube).

Method B.—This method should not be used for practice purposes, since it involves tube-joining and shaping only, and not the fundamentals of 'gathering the glass'. The method is of great utility however, when a large bulb is required in the laboratory, where it would be inconvenient and impracticable to blow on such a large scale.

Fig. 48.—Position of hands for Blowing a Bulb at the End of a Tube



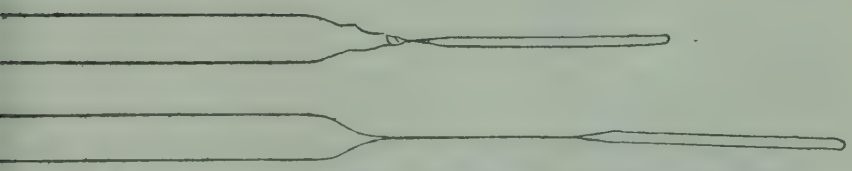


Fig. 49.—Sealing-off after Bulb-Blowing. Method A (Part IV

(i) Join, using the previously described technique, a fifteen centimetre length of twenty-four millimetre diameter standard wall tubing, to a similar length of six to eight millimetre diameter thin walled tube.

Fig. 50.—Bulb-Blowing by Method B

(ii) Draw-off the large tube by heating with a strong, pointed flame, in the area A, in the diagram, and seal the end B hemispherically, as indicated by the dotted line in the diagram.

(iii) This cylindrical form is now treated as a bulb which has been blown from a collected mass of glass, and is heated in a large brush flame, which must be of sufficient size to envelop the bulb. The bulb is allowed to collapse slightly and thicken, and in so doing it assumes a more spherical or 'drop' shape. Heat uniformly, rotate, and finally blow up to the required size.

BLOWING A BULB ON A TUBE.

Bulbs on tubes are often required, and skill in producing them is always a valuable asset in almost any laboratory.

Draw-off thirty centimetres of six to eight millimetre diameter, standard wall, soft soda tubing. Fire-polish the open end. A large Bunsen burner of the Meker type can be used for this work, thus dispensing with the air supply necessary for the blow-pipe. The skill in blowing bulbs in the middle of tubes, lies in turning both hands at the same rate and maintaining their relative position.

Method.—Heat a portion of the middle of the tube

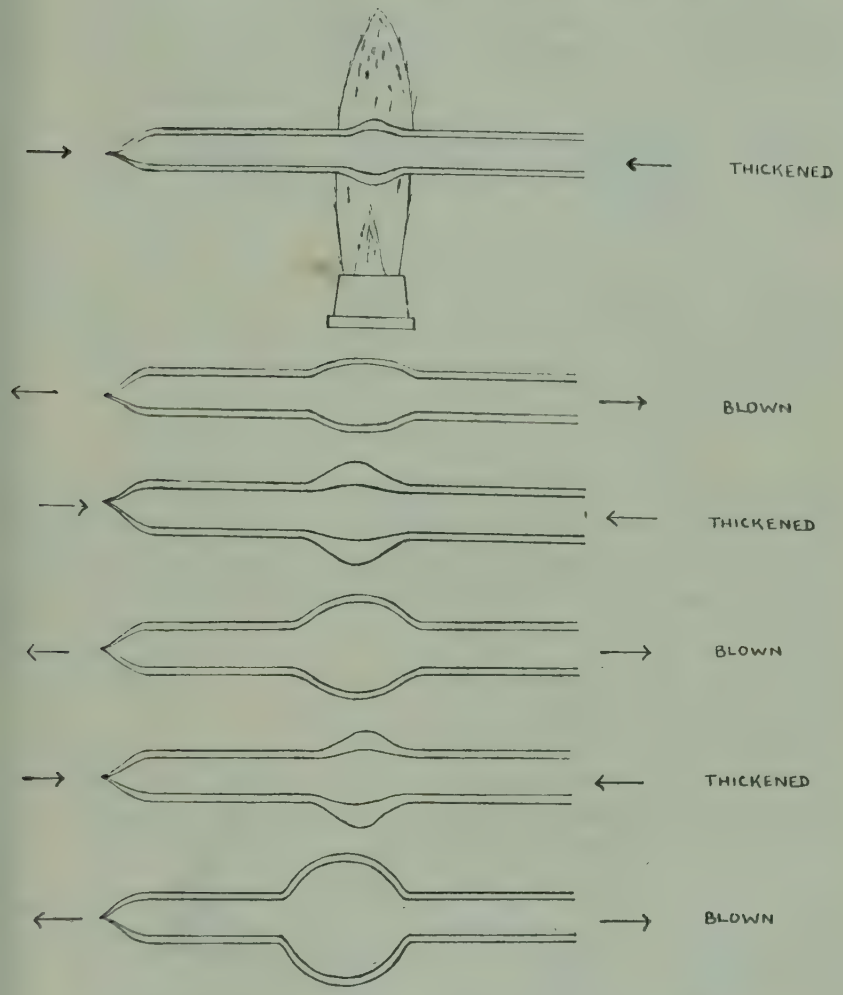


Fig. 51.—Blowing a Bulb on a Tube

niformly by rotating in the flame. Push the ends of the ıbe gently together until a thickening of glass has ɔllected. Blow out very slightly. Re-heat and rotate ırefully and, as the glass becomes fluid, urge the tubes ɔgether and collect more glass in the area. If the tube ıows signs of closing, blow it out with one or two puffs. epeat the operation of thickening and blowing up,

until a thick walled bulb of about two and a half time the diameter of the tube is formed.

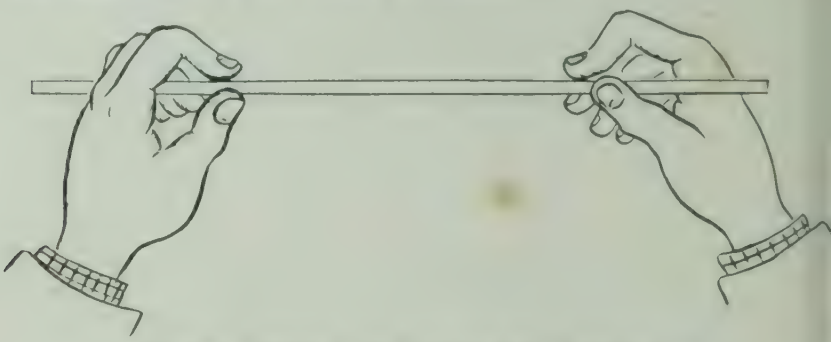


Fig. 52.—Method of Holding Tube for Blowing

HOLDING THE TUBE FOR BLOWING. [Figs. 52 and 53]

The position of the hands is of considerable import ance, and, although the hand positions described may at first sight seem rather awkward, they are the outcome of considerable experience.

During the heating of the bulb, the tube is rotated in the position indicated in the diagram. Left hand curves over the top of the tube supporting it lightly on the end of three fingers of the hand, and rotating the tube with the thumb and index finger.

Right hand under the tube with palm facing upwards, rotating the tube with the thumb and index finger, and supporting it lightly on the middle and third finger.

Fig. 53.—Position of Hands for Blowing a Bulb on a Tube

This greatly facilitates blowing, which is then brought about by lifting the right hand to the mouth, and lowering the left hand until the tube is vertical.

This movement, whilst executed with speed, should be done smoothly and without altering the relative position of the two hands. The technique, naturally, can only be acquired after several attempts.

The tube should be rotated through about two revolutions during the final vertical blowing, in order that any tendency to bend may be corrected.

As before, annealing is not necessary.

CHAPTER V

CONSTRUCTION AND REPAIR OF APPARATUS

Construction.

The order in which the constructions are arranged enables the glass-blower to deal with the matter progressively. Requirements in bending, joining, and bulb blowing, etc., being given before the appropriate hints in each case.

When a group of students are tackling a piece of apparatus or a model, the design should be drawn out in full scale on cartridge paper. The stand or support can then be designed, drawn out carefully, and made by another group. It should be painted or varnished before the glasswork is assembled on it. In the following examples, all of which have been constructed in the author's school laboratory, the glass used was universally of the soft soda variety, to avoid unnecessary expenditure in material and fuel.

(1) Apparatus for the Partial Purification of Mercury. [Figs. 54 (*a*) and (*b*)]

Technique Involved.

(*a*) Joining of small gauge tubes to larger gauge tubes.
(*b*) Bending.
(*c*) 'Drawing-off' and jet making.

Tubes A and D are twenty millimetres in diameter and should each be thirty centimetres long, drawn-off and sealed hemispherically at B, and E, and a fourteen centimetre length of six-millimetre diameter standard wall tubing joined to each tube. The narrow gauge tubes are then bent as indicated in the diagram. The bend F being not more than three centimetres above the base level of tube E, and C not more than ten centimetres above B. F and C can also be capillaries.

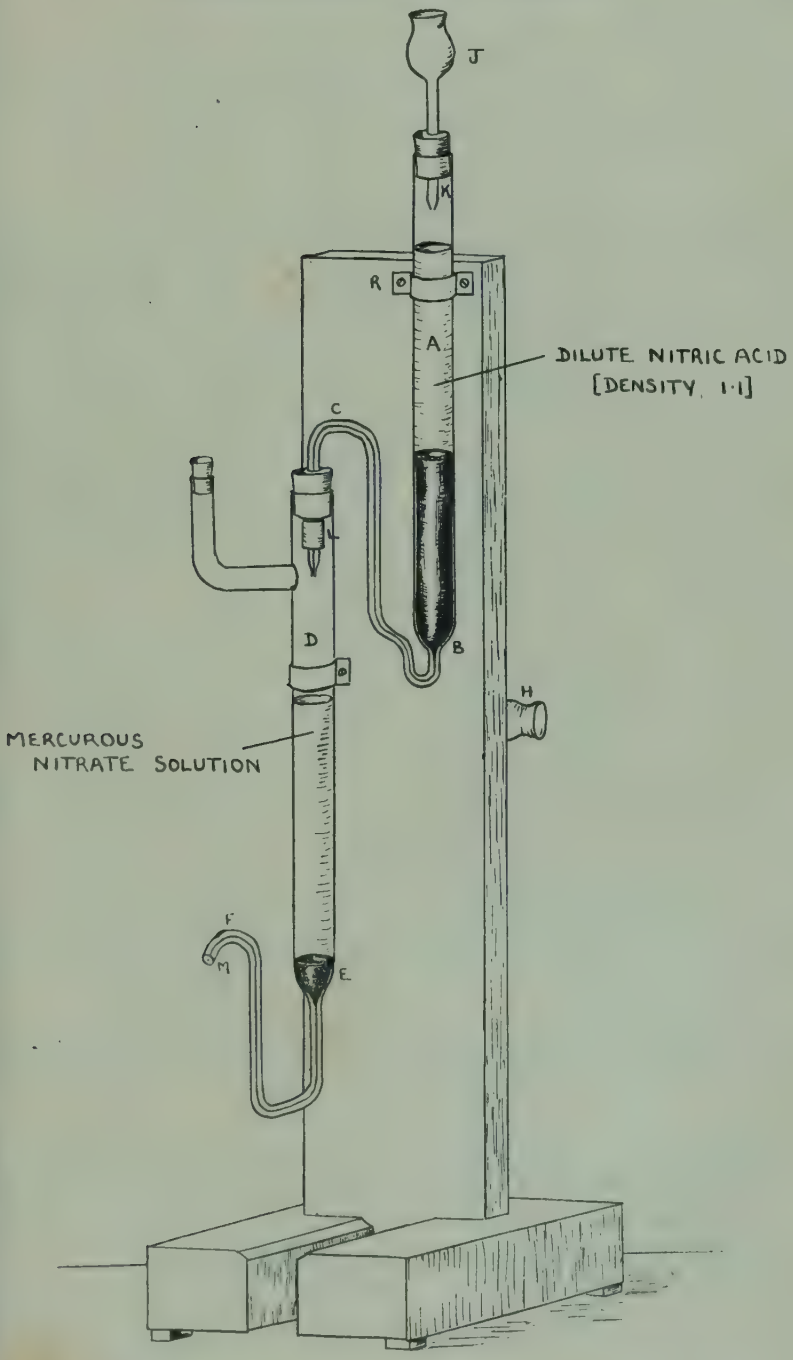


Fig. 54 (*a*) —Apparatus for the Partial Purification of Mercury

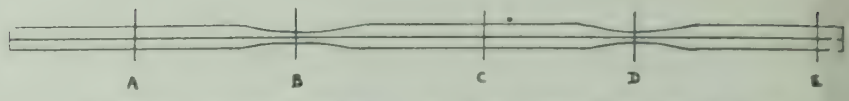


Fig. 54 (*b*)—The Preparation of Jets from Capillary Tubing

A twenty centimetre length of one millimetre diameter capillary tubing (six millimetres approximate external diameter), is drawn-off to a series of constrictions, each about half the diameter of the tube. The tube is cut, as in the positions lettered in the diagram, producing a series of jets, each of about three centimetres length. Fire-polish the ends of each jet, and attach to L with small gauge red rubber tubing. Attach a jet in the same fashion to K, the end of a cut-down thistle funnel, into which the mercury is poured. The jets K and L should be such as to allow a fine rain of the metal to fall through the liquids, hence to avoid blocking K at the outset, dirty mercury should be roughly filtered in the usual manner, through a filter cone pierced with pin holes.

R is a light gauge brass strip, bent and screwed over the tube, to attach it to the wooden stand.

In order that the surface of the liquid in D may be kept free from dust, jet L can be made to pass loosely through a cork in the top of D.

H is a spare funnel fitted with a jet and is clipped to the back of the stand for use while J and K are being cleaned. For this latter purpose, dilute nitric acid should be used.

The stand of the apparatus should be varnished, and an enamelled or painted tray of metal placed underneath to catch mercury spilled accidentally.

2. APPARATUS DEMONSTRATING THE INCREASE OF PRESSURE OF WATER WITH HEIGHT. [Fig. 55]

Technique Involved.

(*a*) 'T' joints in tubes of unequal diameter.

(*b*) Sealing tubes.

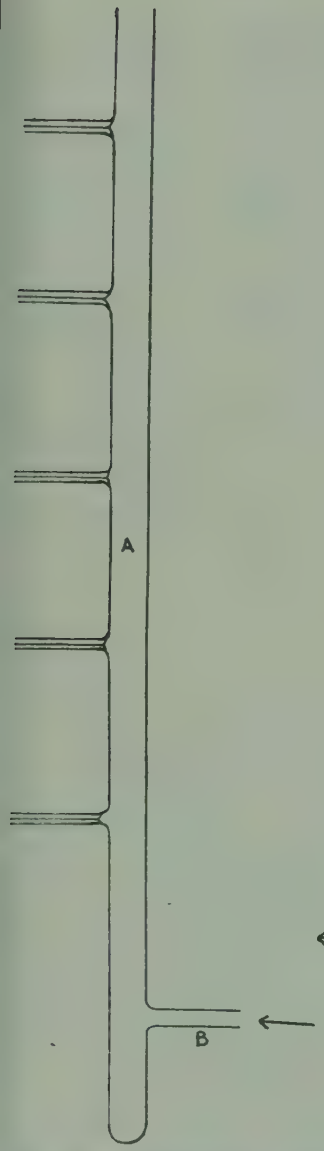


Fig. 55.—Apparatus Demonstrating the Increase of Pressure of Water with Height

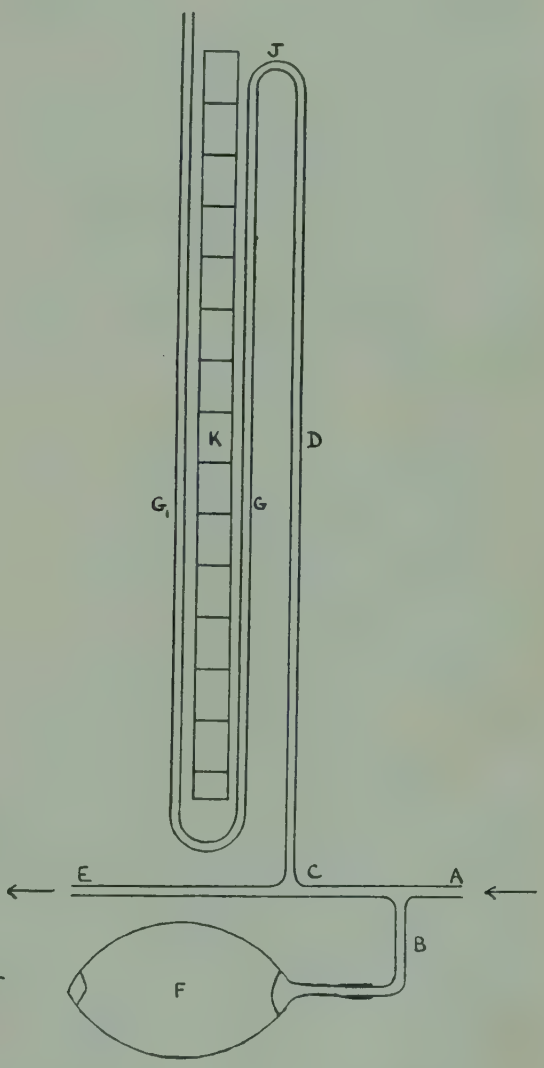


Fig. 56.—Simple Manometer with Reservoir

One end of a hundred centimetres of twenty to twenty-four millimetre diameter tubing, is sealed hemi-

spherically, the other end fire-polished, and an eight millimetre tube sealed at right-angles about two centimetres from the closed end. On the opposite side of the tube A, to this eight millimetre tube, is sealed about six, two millimetre bore, capillary tubes, also at right-angles, and evenly spaced throughout the length of A. They should be blown out for joining to A, cut to five centimetres length, and finally fire-polished at the other end.

The apparatus is best wired to a wooden stand, which can be painted white. The tube B is connected to a water tap, and the level of the water in A should be kept within an inch or so of the top of the tube. The jets from the side-arms can be directed into a sink.

3. CONSTRUCTION OF SIMPLE MANOMETER (FOR COMPRESSED AIR). [Fig. 56]

Technique Involved.

(*a*) 'T' joints in equal diameter tubes.

(*b*) 'U' bends.

(*c*) Joint.

Tube G_1G is formed by fire-polishing the end of a five-foot length of six millimetre tube, and bending it to a 'U' shape at the midpoint. Another length, D, of the same type of tubing is joined on to G, and then bent to form a perfect 'U' at J. A thirty-five centimetre length, EA, of similar tubing is prepared by fire-polishing the ends, and joining on a twelve centimetre side tube B, which is then bent at right-angles to take the rubber reservoir (a football bladder) F. EA is then joined to tube D at C, tube D being at right-angles to B so that the reservoir F can rest on the base of the stand.

The stand should have a flat wooden upright to which D, G and G_1 should be fixed, either by grooved blocks, or by wires passing through holes in the board. Blocks are most satisfactory. The tube G_1G is half filled with red ink or eosin solution, and a three centimetre length of sealed tubing placed loosely over the open end of G_1,

o keep dust out. A paper scale is glued to the stand etween G and G_1, after the stand has been painted hite.

The air tube from the bellows or compressor is con-ected to A, and the outlet to the blow-pipe or apparatus, oined to E. The scale and liquid levels are easily seen rom a distance; an important feature in a school aboratory.

. Illustration of Expansion of Gases, Using Air. [Fig. 57[

Technique Involved.

(*a*) Bends.

(*b*) Bulb-blowing.

(*c*) Joining large diameter to small diameter tubes.

A five-foot length of four millimetre tubing, is bent nto a 'U' as shown in the diagram. Fourteen centimetres rom one end, a bend of about 30° is made outwards, so hat the tube L is capable of being fitted through a cork rooved at its perimeter P, into a seven inch by one nch boiling tube of coloured liquid. Both ends of the U' tube ABC are polished in the flame.

A twenty-four centimetre length of twenty millimetre iameter standard wall tubing G, is drawn-off, and a our centimetre length, of four millimetre tubing K, oined to one end, and its other end fire-polished. A niform bulb H, not exceeding twice the diameter of the ube, is blown at the other end of G. This tube G is now ttached to limb A of the inverted 'U' tube by means of piece of small-gauge pressure tubing, sufficient to allow mple movement of tube G.

The apparatus should be mounted on a stand and a learly marked scale placed behind tube C. By removal f bulb G and gentle suction the indicator liquid in the ube E may be brought on to the scale at a suitable osition such as D. The rubber tubing at K is then queezed and the bulb tube replaced.

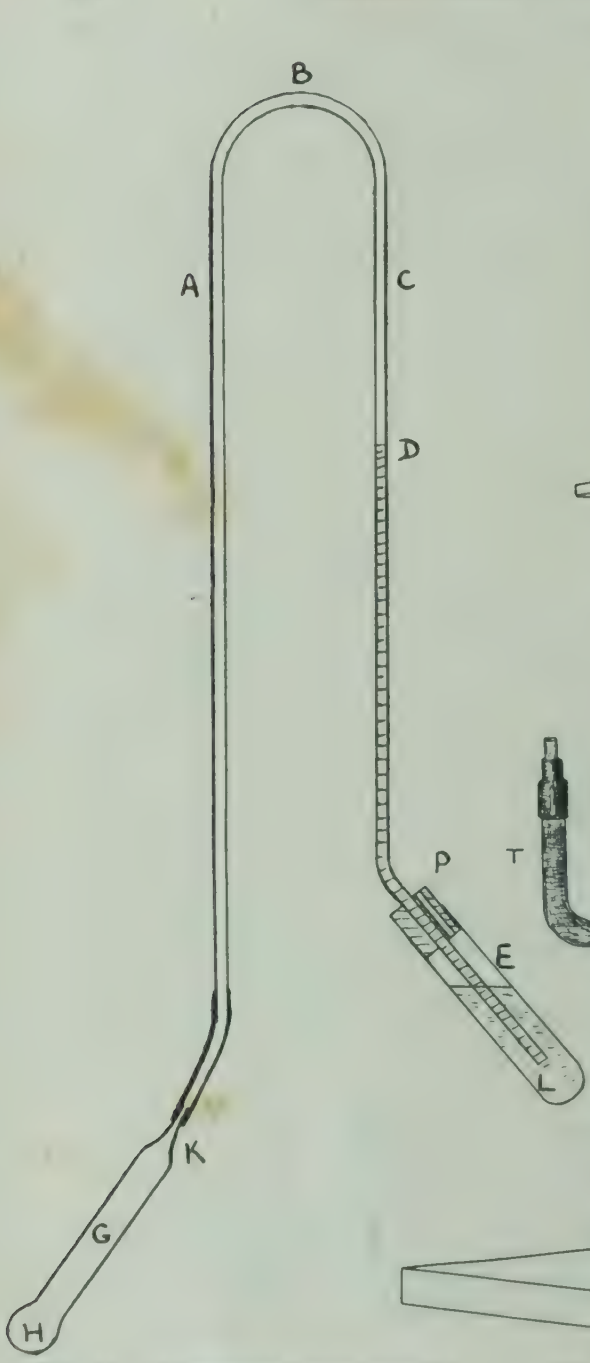


Fig. 57.—Apparatus Demonstrating the Expansion of Gases

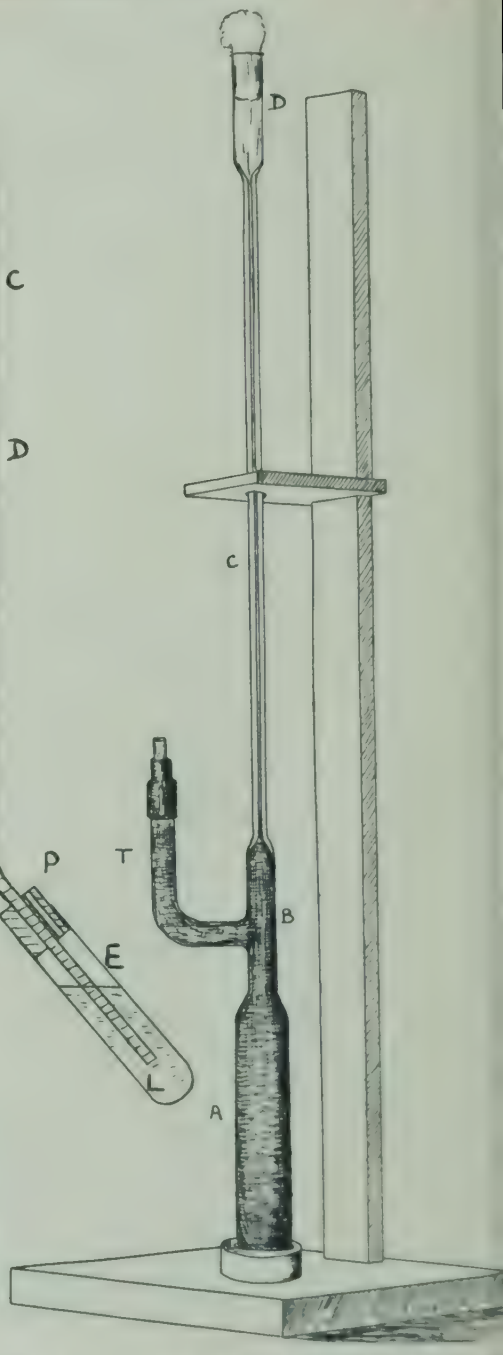


Fig. 58.—Apparatus Demons the Expansion of Liquid

The apparatus is quite portable and the warmth of the hand gives sufficient movement of the indicator liquid to be clearly observed by an entire class.

. ILLUSTRATION OF THE EXPANSION OF LIQUIDS. [Fig. 58]

Technique Involved.

(*a*) Sealing wide tubing hemispherically.
(*b*) Joining capillary to wide tubing.
(*c*) 'T' joint.

A ten centimetre length of three centimetre diameter standard wall tubing A, is sealed and blown hemispherically at one end. The other end is drawn-off to take a four centimetre length of eight millimetre tubing B. A six centimetre length of six millimetre tubing T is joined to the side of tube B and bent at right-angles, two centimetres from its joint with B, as in the diagram. The open end of tube T is then bordered or rimmed out to receive a rubber stopper. This side tube is used for filling the bulb A and levelling up.

One end of a fifty centimetre length of milk-scale capillary tube is blown out to receive a six centimetre length of eight millimetre diameter tubing, the top of which is rimmed. This acts as a repository for cotton wool, which excludes dust and retards evaporation. The other end of the capillary is then blown out and joined on to B. Care should be taken to make each of the joints symmetrical.

The apparatus is filled with a coloured indicator liquid through tube T, and the level arranged approximately a third of the way up tube C.

The capillary chosen should not be of too fine a bore so that the apparatus can be conveniently used for demonstration purposes. It should be easily detachable from a wooden stand, in order to place the bulb in a beaker of hot water, etc.

A sliding scale of carboard, as indicated in the diagram, is most conveniently used on the tube C.

6. APPARATUS FOR THE ELECTROLYSIS OF WATER. [Fig. 59]

Technique Involved.

(*a*) Preparation of electrodes.
(*b*) 'H' joint.
(*c*) Sealing of glass stopcocks on to tubes.
(*d*) 'T' joint.

Two tubes H and J of length fifty centimetres each, and diameter fifteen millimetres, are sealed hemispherically. Two glass stopcocks A and B (for economy these can be removed from damaged burettes), are then fused to the sealed ends of these tubes after preparation. The opposite ends are polished in the flame. The double 'T' joint, or 'H' joint, is then made with an eight millimetre tube CD, fifteen centimetres long, to the middle of which has previously been fused an eight centimetre length of eight millimetre diameter tubing K. Tube CD being bent slightly at G, as in the diagram, while this joint is being made.

The joints at C and D are made while the tubes J and H are securely clamped in weighted retort stands. For amateur work, this support is essential, otherwise the weight of the limbs H and J will tend to snap off the joint as it is nearing completion. One of the joints C or D is, of course, made and annealed before clamping in position for the final joint. Tube K is connected with pressure tubing to a separating funnel of acidulated water, acting as a reservoir.

E and E_1 are platinum disc, or wire coil electrodes fused into 'U' tubes of four millimetre tubing filled with mercury, and covered at the open end with a four centimetre length of six millimetre diameter tubing which has been closed at one end.

The bends of the 'U' shaped electrodes should be gradual enough to allow rubber stoppers to be pushed on with the aid of a lubricant such as glycerine and soap.

The apparatus is most successfully supported in a

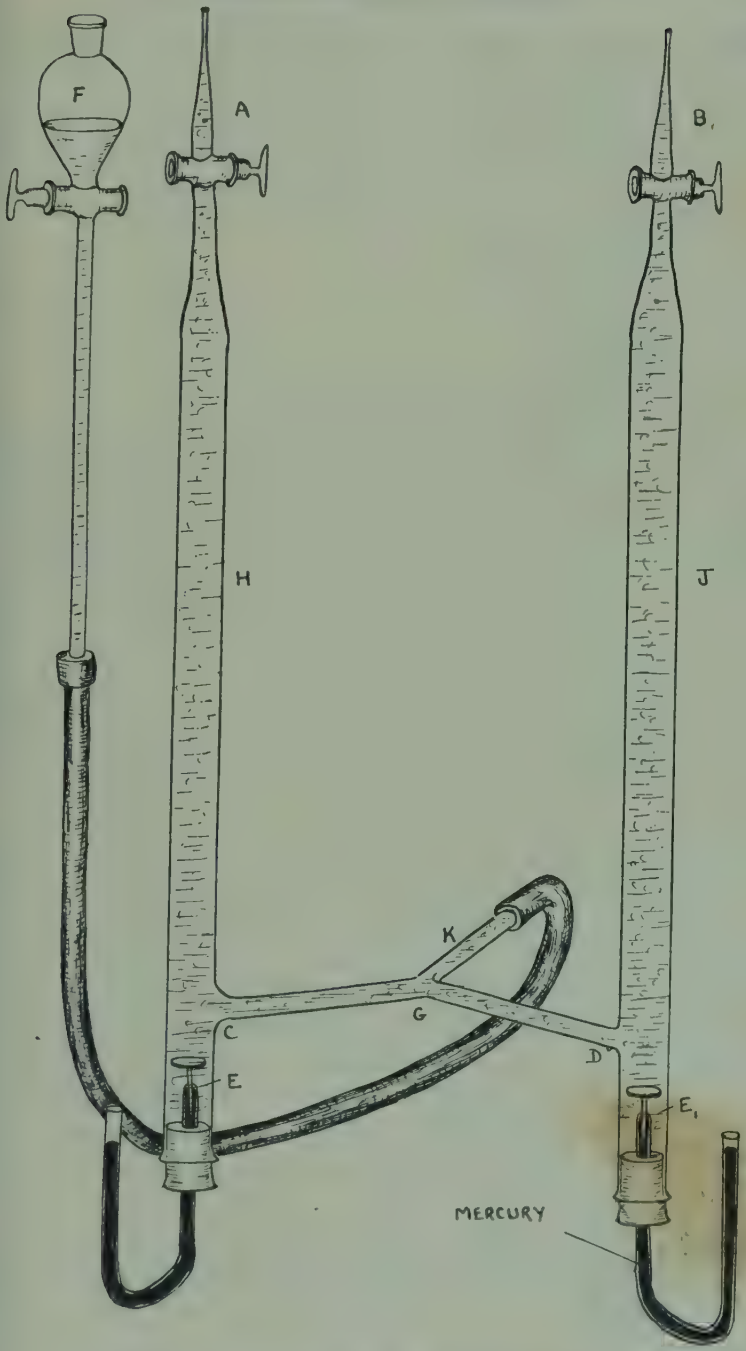


Fig. 59.—Apparatus for the Electrolysis of Water

retort stand carrying a ring, in which the funnel of reserve acid F, may rest.

It is an advantage to open out the rim of H and J slightly, to receive the rubber stoppers of the electrodes.

7. CONSTRUCTION OF AN OZONIZER. [Fig. 60]

Technique Involved.

(*a*) Internal joint.
(*b*) 'T' joints.
(*c*) Bending.
(*d*) Joining tubes of different diameters.

Draw-off a forty centimetre length of four centimetre diameter standard wall tubing. Seal into it a thirty-seven centimetre length of twenty-five millimetre diameter standard wall tubing, supported at the lower end on a plug of cotton wool. (Afterwards removed through drawn-off portion F, with a wire hook.) Anneal the joint carefully, and make sure that B is centred correctly in A. Remove the wool through F, and join on side-tube D consisting of four centimetres of six millimetre diameter standard wall tube. Polish the end of it in the flame and bend it downwards as indicated in the diagram.

Round off tube A at F, using D as the orifice for connection to the blow-tube. Blow out this hemisphere to take a forty centimetre length of fifteen millimetre diameter standard wall tubing, bent to form a 'U' as indicated at G, in the diagram. Polish its open end in the flame, cool and stopper it. Connect the four centimetre long side-tube E, of six millimetres diameter, and polish the end. A five centimetre length of two centimetre diameter tubing, sealed at one end, serves to keep dust out of tube G, which is filled to the extent indicated with concentrated sulphuric acid.

Tube B is filled with dilute sulphuric acid in which is immersed a copper electrode, long enough to pass down the entire length of the tube, and to project two or three

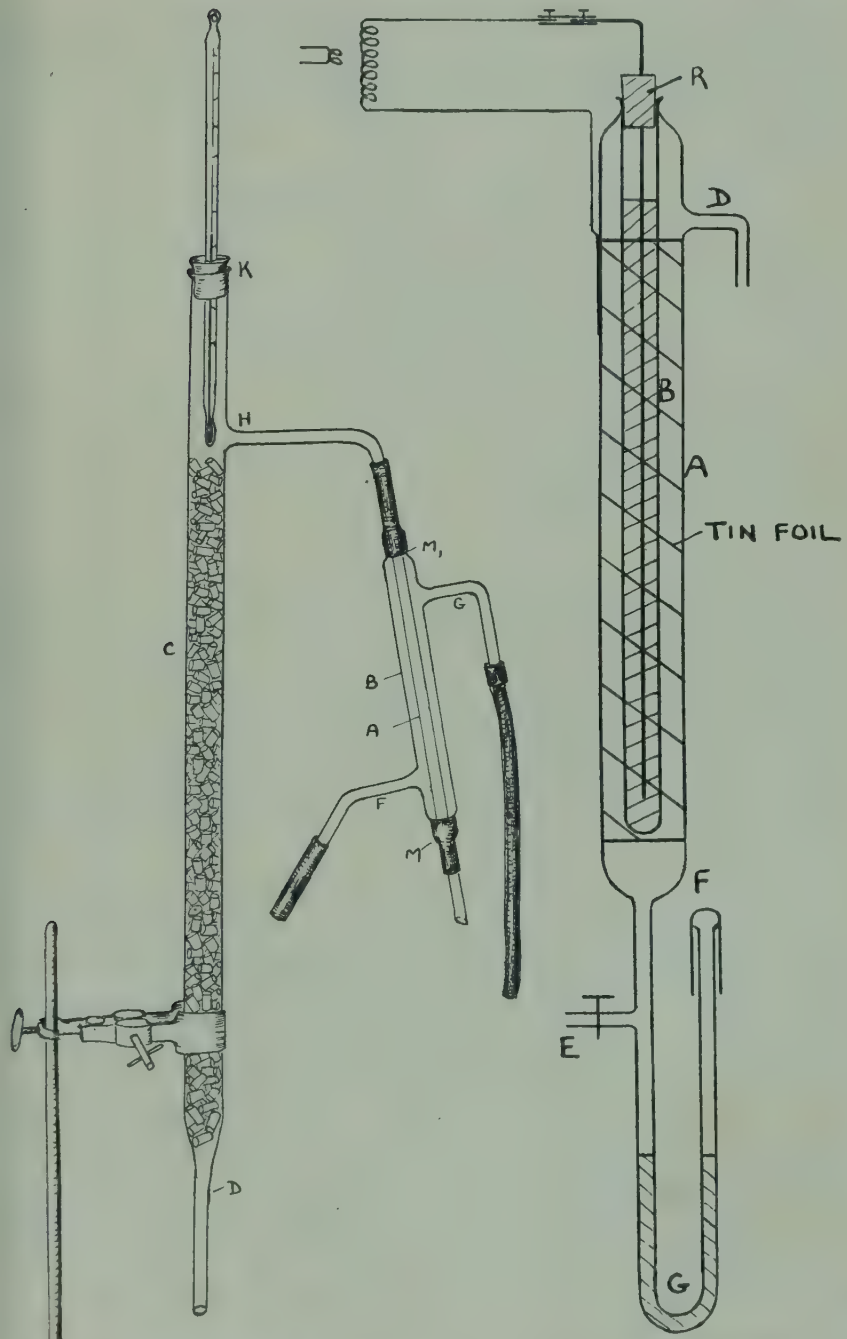


Fig. 61.—Fractionating Column with attached Condenser

Fig. 60.—The Ozonizer

centimetres from a rubber stopper through the centre of which it passes. A sheet of pure tin-foil completely surrounds tube A. This is connected to one terminal of a powerful induction coil and the copper electrode is connected to the other.

Air, or oxygen, which has been dried by passing through a concentrated sulphuric acid wash-bottle, is pumped into the apparatus through tube E. The ozonized air, or oxygen, leaves the apparatus at D, from which it may be led into turpentine.

8. FRACTIONATING COLUMN WITH ATTACHED CONDENSER. [Fig. 61]

Technique Involved.

(*a*) Joints.

(*b*) Bends.

The Column.—A sixty centimetre length of two centimetre diameter standard wall tubing C, is rimmed out at one end K to take a cork, and a twelve centimetre length of six millimetre diameter tubing D, one end of which is ground oblique, is fused on to the other end. A four centimetre length of eight millimetre diameter tubing is joined to the tube C at H and bent to the angle indicated.

The Condenser.—A twenty-six centimetre length of four millimetre diameter standard wall tubing, A, is ground oblique at one end. A water jacket B, sixteen centimetres long, and of fifteen millimetres diameter, is constricted at the ends to take the inner tube A, and is sealed with a fine pointed flame at M and M_1.

Short lengths of six millimetre diameter tubing G and F, are sealed on to the jacket B and bent to hang vertically, as indicated in the diagram. The inner tube A of the condenser is then fused to the eight millimetre tube H.

The tube C is filled with centimetre lengths of two or

ıree millimetre diameter tubing (or small glass beads, available). A space is left opposite to the opening of H, o allow for the bulb of a thermometer passing through cork placed in the neck K.

A Model Gas-Producing Plant. [Figs. 62-67]

Technique Involved.

(*a*) 'T' joints.
(*b*) Joints in tubes of differing diameters.
(*c*) Bulb-blowing at the centre of tubes.
(*d*) Practice in blowing glass to a design.

The layout of the plant is drawn out carefully as lustrated in the diagram, and all the measurements are ıcluded. A wooden base is then constructed and wooden ıpports cut and screwed into position.

The following is an outline of the construction:

The Retort.—The metal canister shown serves as the tort, and should hold about two pounds of powdered oal. The lever lid is sealed on with Plaster of Paris terwards. A $\frac{5}{8}$″ asbestos stopper passes through the d and carries a six millimetre diameter glass tube ading directly into the side of the tar well.

The retort is gas fired, the burner for this purpose eing an iron tube with one end closed, an air hole near ıe other end, and a series of holes bored along its ngth.

Primary Tar Well.—This, already mentioned, receives ıe hot gases and vapours directly from the retort. It as a plug at its base, enabling the liquors to be tapped f. The top is rimmed, and a cork placed in it to facili-te cleaning the unit. A side-tube from here travels owards to the Secondary Well.

Secondary Tar Well.—To the bottom of this, a stop-ock of three millimetres bore is fused for tapping off rther liquors. A side-tube leads to a *Manometer* owing the pressure when the Plant is producing gas.

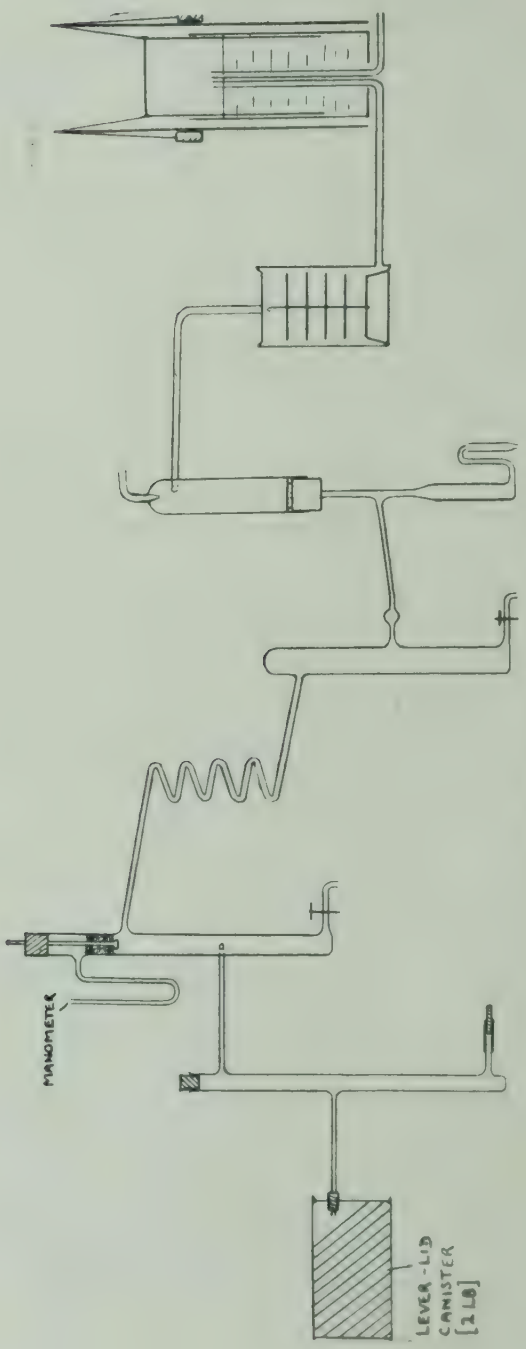


Fig. 62.—A Model Gas Plant

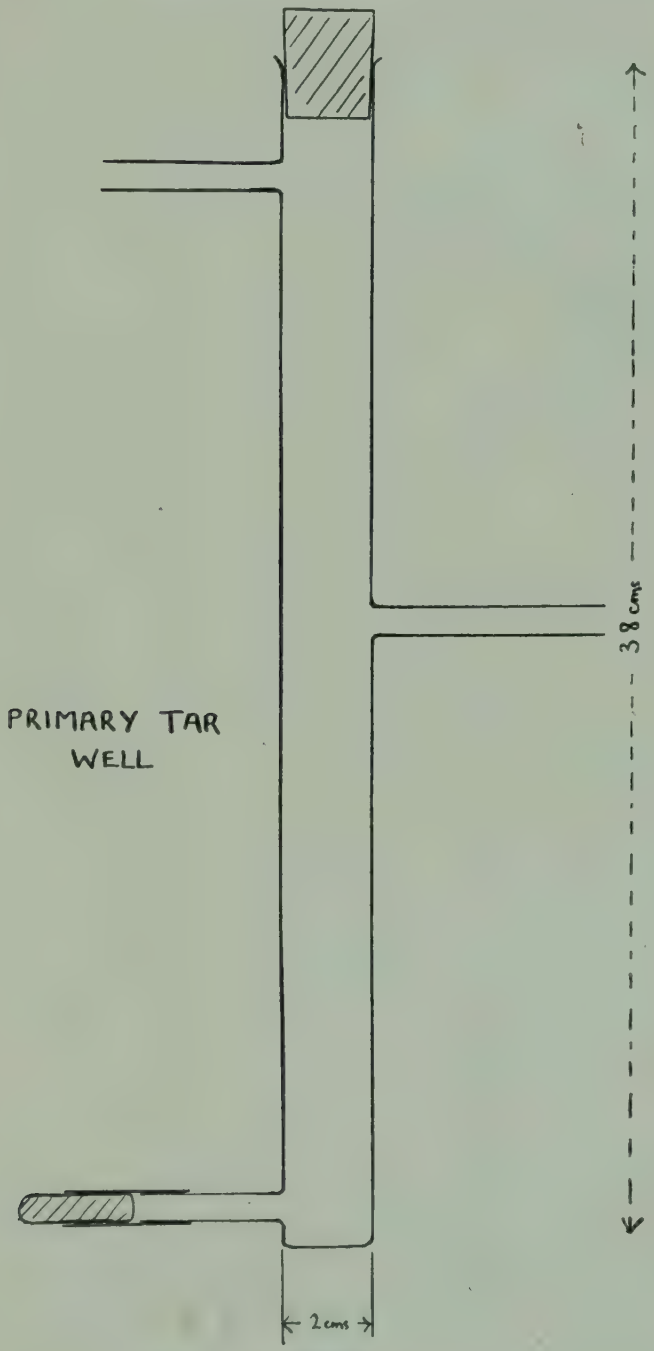


Fig. 63

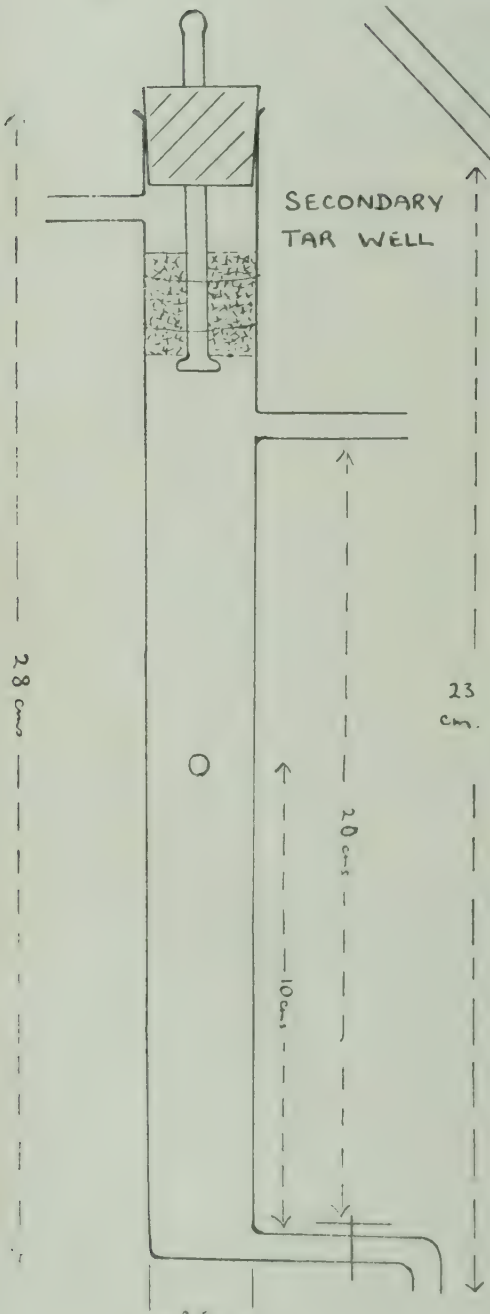

SECONDARY
TAR WELL
28 cms
23
cms.
20 cms
10cms
2·5cm

Fig. 64

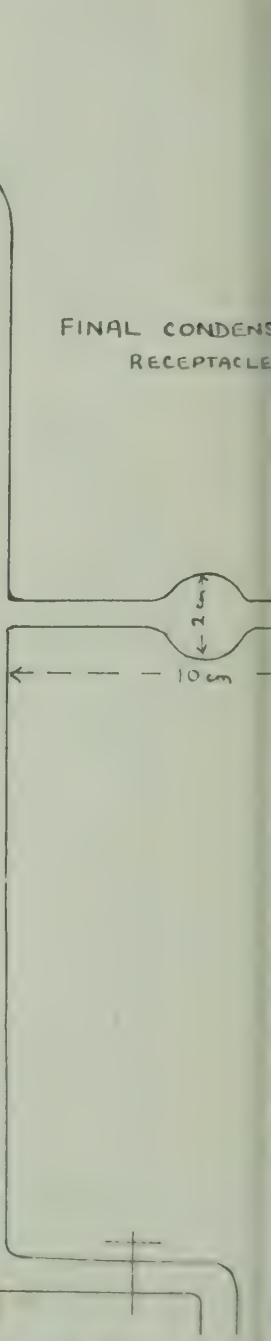

FINAL CONDENS
RECEPTACLE
2 cm
10 cm

Fig. 65

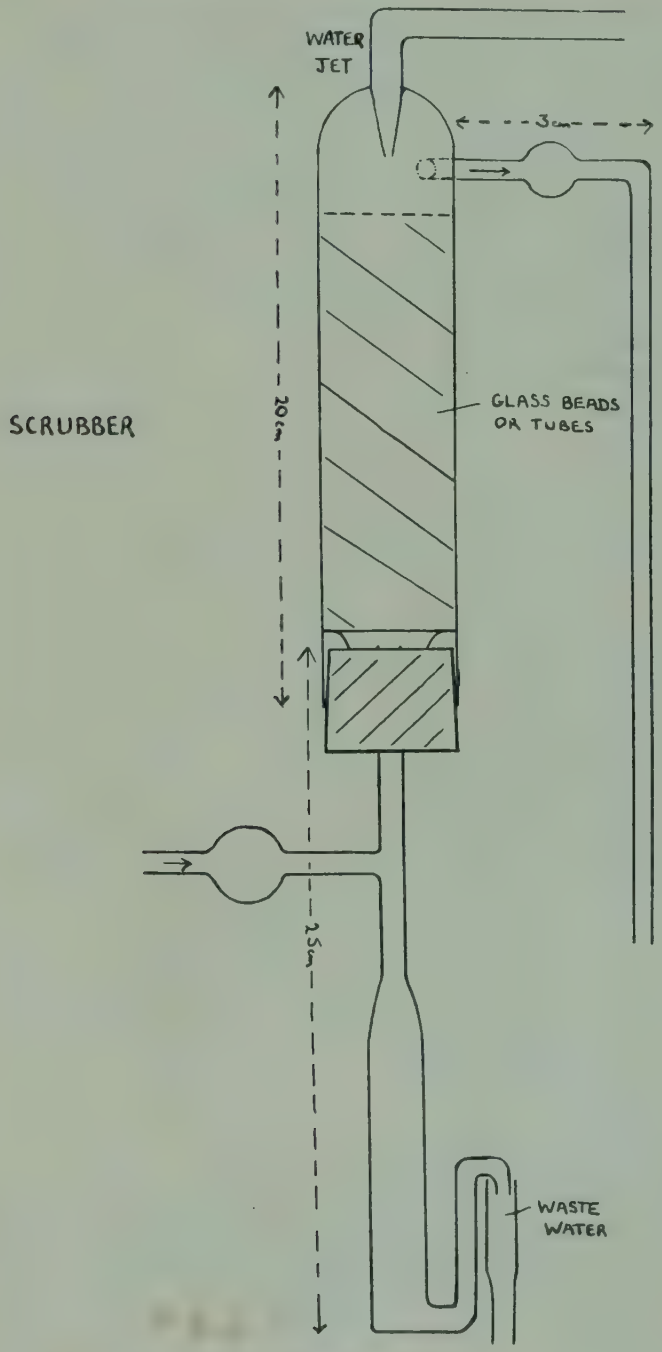

SCRUBBER
WATER JET
3cm
20cm
GLASS BEADS OR TUBES
25cm
WASTE WATER

Fig. 66

Another side-tube leads to a *Spiral Condenser*, and any liquids condensed here flow down into the *Final condensate receptacle*, at the base of which is a stopcock where with to tap off these liquors. From here the gas passes to the base of a *Scrubber* up which it filters through a column of glass tube fragments, over which water flows continuously. The bottom of the scrubber consists of a water trap maintaining a certain level of water against the gas pressure, and allowing it to flow away as it accumulates from the spray at the top of the tower.

On reaching the top of the tower, the gas passes out through a side-tube into a *Purifier*. This consists of a two pound, lever-lid tin, fitted with tinplate baffles soldered to a centre wire, and sprinkled with lime. From here the gas passes to the gas holder, which is supported by lead weights partly balancing the weight of the holder, and connected to it by strings passing over pulleys. The holder is an inverted canister of the proportionate size indicated in the illustration. It is suspended in a canister of medium grade lubricating oil instead of water, which rusts the metal away very rapidly, and evaporates readily. The gas passes into the holder through the base, into which a metal inlet tube is soldered. Similarly, an outlet-tube to the burner is soldered through the base of the gas holder. For temporary measures, a two-holed bung of rubber carrying glass tubes, may be substituted. The bung is, of course, ruined in a few months by the oil.

10. MODEL DOMESTIC HOT-WATER SYSTEM. [Figs. 68-69 and Frontispiece]

Technique Involved.

(*a*) Sealing.

(*b*) Joints and bends in situ.

The main item of glass-blowing here, is the preparation of the boiler. Although this can be made of Monax, Hysil, or even Pyrex, to withstand the strains of heating and cooling, it has been made of ordinary soft soda

glass, and found to work satisfactorily over a period of years.

A twenty centimetre length of three centimetre diameter standard wall tubing B is drawn-off and sealed hemispherically at, say, D. It is annealed carefully, and a ten centimetre length of eight millimetre diameter standard wall tubing C, of the same batch as B (if possible), is sealed on at right-angles, as indicated in the diagram. This joint is annealed. The opposite end to

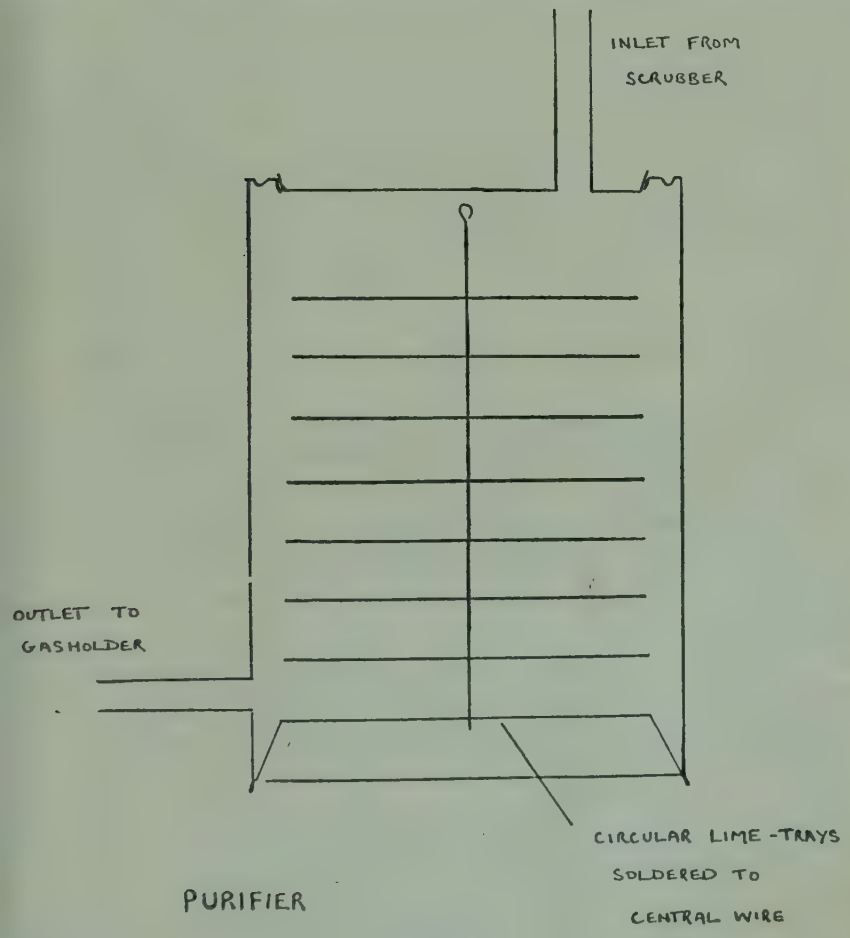


Fig. 67

D is now sealed, using C as the blow-tube. The end is annealed, and a ten centimetre length of eight millimetre diameter standard wall tubing A, is sealed on in a similar position to C. A further ten centimetres of the same tubing is fused to C at right-angles, and at about five centimetres from B. This is connected ultimately to the main drainage tube. Fire-polish the ends of A, C and E.

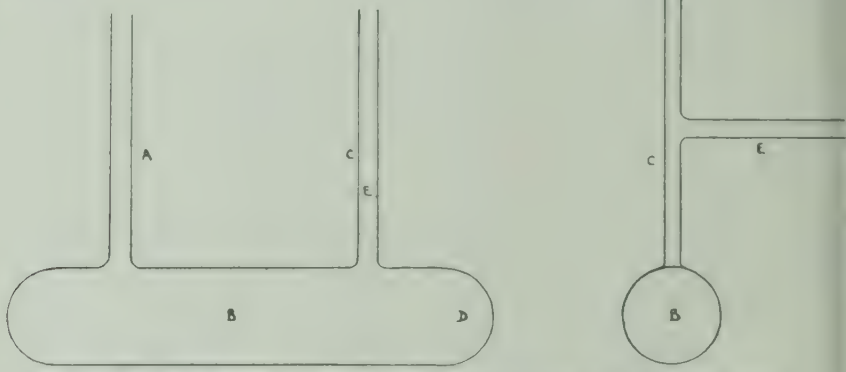


Fig. 68.—The Glass Boiler of the Domestic Hot-Water System

Over a large luminous flame bring the whole structure to almost softening point. Maintain for a few seconds, then cool slowly. This boiler is wrapped in mica sheets and mounted in a copper stand, under which the gas heater is fixed. Between the heater and the mica, a further protection is included in the form of an iron gauze screen.

The long conducting tubes to the storage cistern are of the same tubing as A and C, and are fused on to these tubes when their other ends have been attached to the cistern. A Fahrenheit thermometer is attached with adhesive tape wrappings to each conducting tube, to show the difference in temperature between the ascending hot water, and the cooler returning stream.

The boiler and the storage cistern form a complete circuit. Water is tapped off from the top of the storage

stern by a six millimetre diameter tube, which runs own the edge of the wooden framework, giving off two lass stopcocks on its way. The upper, to a white ainted bath of tinplate, boxed in with wood. The lower, o a small tinplate bowl. Both the bath and the bowl re fitted with drainage tubes which join a common rain on the baseboard of the model. This tube passes aste water into a laboratory sink.

An expansion pipe from the top of the storage cistern ends over into the supply tank on the top of the appara-us. This tank is bored to receive a rubber bung from ne centre of which, a six millimetre diameter supply ube passes into the base of the storage cistern. A mains upply tube, also of six millimetres diameter, from one f the laboratory taps, passes along the baseboard of the pparatus, up the edge of the back, and shaped to the pper structure, it finally curves over the rim of the upply tank.

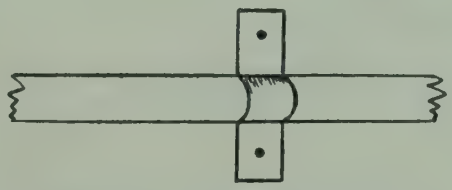


Fig. 69.—The Lead Tube-Bracket

All the tubes passing along the woodwork are secured y lead strips, shaped, and tacked over the tubes with mall brads as illustrated in Figure 69.

Where a joint has to be made close to some woodwork, small sheet of soft asbestos board should be placed etween the tube and the wood.

'REPARATION OF BEAKER FLASKS FROM BURNED-OUT ELECTRIC LAMPS.

During a period of temporary shortage of laboratory lassware, senior boys in the author's school laboratory

made a liberal supply of flasks from discarded lamp
These burned-out lamps were scratched at the neck wi
a file, and a hot wire applied until the crack travell
uniformly round. The bayonet cap and the filame
support, with the remains of the filament, were draw
out and preserved for future experimental work. T

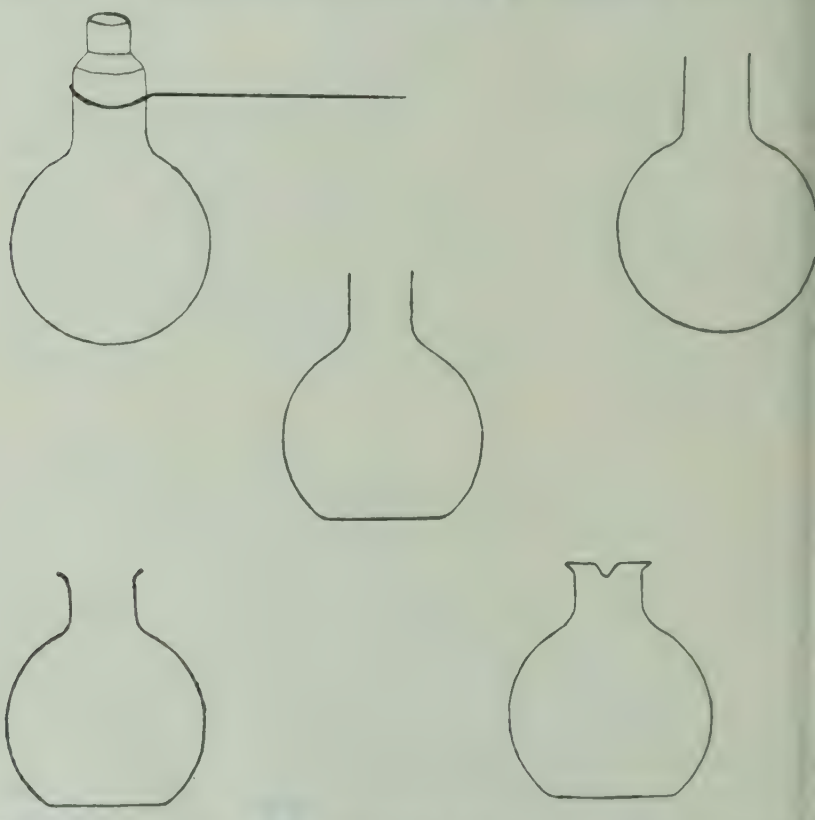


Fig. 70.—Production of Beaker-Flasks from Discarded Electric Lam

lamp glass was washed and carefully dried. A larg
accumulator tank of dilute chromic acid served as
cleaning bath for several glasses at a time.

The next stage was the flattening of the bottom of th
bulb by heating it strongly in the blow-pipe flame, an

ressing on to an asbestos pad. The neck was then mmed out, using the tool described in the first chapter, nd the vessel used in this state as a flat-bottomed flask, r most satisfactorily, as a beaker-flask. This latter is chieved by heating the rim at the point required and ressing outward with the edge of a file.

With sufficient practise, the whole process can be ompleted in a very short time. Mistakes are not xpensive, since the supply is virtually inexhaustible, nd the size can be varied from 100ccs., or less, to about ,000 ccs.

EPAIR OF BROKEN MEASURING CYLINDERS.

Measuring cylinders are an expensive item, and in irtue of their relative instability, have a high mor- ality in school laboratories. Even the protective rubber ings do not seem to diminish the fatalities to any great xtent. They can be restored to use for many laboratory perations by carefully cutting off the shattered top

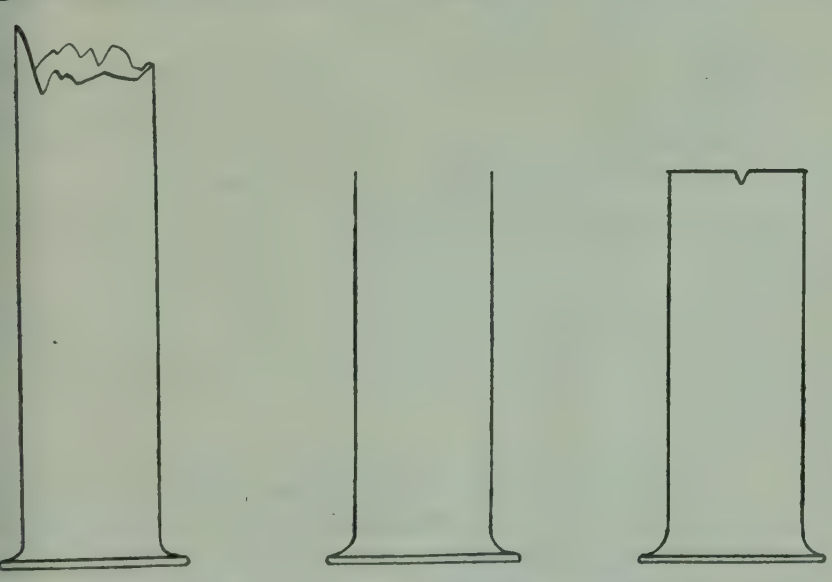


Fig. 71.—Repair of a Measuring Cylinder

with the aid of a file scratch and a hot wire. In the cas of a large two litre cylinder of thick glass, the previously described turntable method can be effectively employed

The rim of the freshly-cut tube should be heated in thin, batswing flame, until it has just softened. It ca then be spun out with a tool. More localised heating a one point, and slight pressure with the edge of a file forms the lip. Care should be taken to see that the li is in the correct position and that the graduations sha be on the same side as the operator when pouring out liquid.

It will be observed from this, that the necks of flask can be repaired in the same manner.

HINTS

1. Make careful diagrams of the work you are goin to undertake, after you have first acquired som skill in the construction of simple bends and joints Keep to the diagram as closely as possible, in th construction of the apparatus.
2. Think out the simplest methods of working first What appears to the layman as a vitreous phe nomenon, is generally the successive application o simple joining, bending and bulb-blowing.
3. Remember to fire-polish the ends of tubes in th flame before putting them into your mouth.
4. Do not mix the glass to be used for one job. Selec it all from the same batch. Different batches fron the same firm often vary in softening range, etc.
5. CRACKS.
   (*a*) Large cracks are usually fatal and mean discarding the material and beginning again
   (*b*) Moderate or small cracks in soft soda glass can sometimes be sealed up when the apparatus is in the course of being made, and

the glass is sufficiently warm. A crack in cold soda glass frequently spreads during the warming up process. Cracks in Pyrex, Monax and Hysil glasses can be sealed up with much greater facility, owing to their lower coefficients of expansion. In the case of soda glass, heating must be commenced very gradually. Start by warming the apparatus about one foot above a luminous flame. Gradually bring the flame nearer, wafting it about the region of the crack. When the glass over the whole area is very hot (by now the flame should be non-luminous, by admitting a little air), quickly reduce the gas and air of the blow-pipe to give a blue, pin-point flame.

The blow-tube should be connected to the apparatus, and gentle *suction* applied while the flame is played directly along the crack, sealing it slowly from end to end.

(*c*) Star-cracks, often occasioned by a blow or the impact of a small, hot particle, may be sealed in a similar manner. Warming up the area of the crack gradually, then heating the crack itself with a pin-point flame, while applying gentle suction to the apparatus by means of the blow-tube.

A COURSE OF TRAINING IN SIMPLE GLASS MANIPULATION

Standard wall tubing should be used throughout.

Lesson I.

THE QUALITIES OF SOFT SODA GLASS.

(*a*) Examination of the softening and viscous nature of glass using a Bunsen burner (Meker preferably), and pieces of two or three millimetre diameter glass rod, and scraps of tubing. Allowing drops to form. Drawing softened rod into fine hairs, the flexibility of which is noted. Squeeze 'blobs' of soft glass rod with warmed pliers.

(*b*) Joining and bending pieces of rod.

(*c*) Rapid heating of rod to cause breakage, illustrating the formation of strains greater than the rod can tolerate.

(*d*) Rapid cooling of hot rod in water to cause breakage.

(*e*) Examine a piece of devitrified glass.

Lesson II.

THE QUALITIES OF SOFT SODA GLASS (*continued*)

(*a*) The preparation of Rupert's Drops:
Allow drops of molten glass to fall into water, snap off the tip and note the disintegration. Strike the bulb of the drop and notice its strength.

(*b*) Cutting glass rod and tubing with:
1. A triangular file.
2. A glass-knife.
3. A hot iron wire.

Lesson III.

Elementary Operations Using Soft Soda Glass.

(*a*) Polishing the ends of tubes in a Bunsen flame. The tube diameter must be maintained at the end.

(*b*) Bending glass tubes in the batswing flame. Start by using two millimetre diameter tubing and work up to ten millimetres.

Lesson IV.

The Blow-pipe.

(*a*) Examine a gas and air blow-pipe. Dismantle and re-assemble it. Connect it up to the gas and air supply, and practise obtaining the different flames, using all the available jets. Become adept at changing over quickly from one flame to another.

(*b*) Try the effect of the fine or 'pin-point' jet, on pieces of scrap glass tube.

Lesson V.

Straight Line Joints, Hemispherical Seals and Blowing-out.

(*a*) Using a pointed flame, make straight joints in six millimetre diameter tubing. Try to achieve uniform rotation with both hands.

(*b*) Using a Meker burner, practise hemispherical sealing of eight to twenty millimetre diameter tubing.

(*c*) Seal off the ends of six millimetre diameter tubes and blow-out. Brush away the film of glass with a file.

Lesson VI.

Straight Line Joints in Larger Tubing.

Make one joint in six millimetre diameter tubing, one in eight millimetre, one in ten or twelve, and

one in fifteen millimetre diameter tubing. Do not be satisfied with an irregular finish. Continue until the joint is smooth and the wall thickness uniform.

Lesson VII.

BULBS IN THE MIDDLE OF TUBES.

(*a*) Using a Meker burner, blow bulbs along tubes of varying diameters, from four to eight millimetres.

(*b*) Using a brush flame on the blow-pipe, blow bulbs along a ten millimetre and a fifteen millimetre diameter tube. Rotation here is very important.

Lesson VIII.

REVISION OF TUBE BENDING. RIGHT-ANGLE BENDS.

(*a*) Revise *Lesson III*, part (*b*).

(*b*) Make a right-angle bend in a fifteen millimetre diameter tube, using a large brush flame. Correct any kinks by use of the blow-tube.

Lesson IX.

'T' JOINTS AND BULBS AT THE ENDS OF TUBES.

(*a*) Make two 'T' pieces using eight millimetre tubing.

(*b*) Using six and eight millimetre diameter tubing and a small brush flame on the blow-pipe, blow four regular bulbs.

Lesson X.

REVISION OF STRAIGHT LINE JOINTS. 'U' BENDS.

(*a*) Revise *Lesson V*, part (*a*).

(*b*) Make one 'U' tube of six millimetres diameter, and one of eight millimetre diameter tubing, using a batswing burner.

Lesson XI.

Revision of 'T' Joints. Jet Making.

(*a*) Make a 'T' joint using six millimetre, and one using ten millimetre diameter tubing.

(*b*) Draw-out eight uniform jets from six millimetre diameter tubing. Uniform rotation is essential here.

Lesson XII.

Joints in Tubes of Differing Diameters. Joining Capillary to Ordinary Tubing.

(*a*) Using *Methods I and II* described in the text, join six millimetre to ten millimetre, and eight millimetre to fifteen millimetre diameter tubing:

(*b*) Join a length of six millimetre diameter capillary tubing to a piece of similar diameter ordinary tubing. Repeat until the joint is uniform.

Lesson XIII.

Rimming and Internal Joints.

(*a*) On the end of a thirty centimetre length of approximately twenty-five millimetre diameter tubing, practise rimming. Cut off the rim with a hot wire. Repeat until a smooth uniform rim is obtained.

(*b*) Make two internal joints, one following *Method I*, and the other, *Method II* of the text. Use a six millimetre and a twenty-four millimetre diameter tube for each.

Lesson XIV.

Revision of Bulbs in the Middle of Tubes. Electrode Construction.

(*a*) Revise *Lesson VII*, part (*b*).

(*b*) Prepare an electrode using 26 S.W.G. platinum wire, and an eight centimetre length of six millimetre diameter tubing. Follow the text closely.

Lesson XV.

REVISION OF 'U' BENDING. PREPARATION OF THE CLOSED DOUBLE JOINT. PRACTISE IN 'FILLING'

(*a*) Revise *Lesson X*, part (*b*).

(*b*) Make a closed double joint, following carefully the method described in the text. Use twenty-four millimetre and six to eight millimetre tubes as suggested. If the space between the final joint is too big to close by using the natural elasticity of the glass, 'filling in' with a drawn-off spindle of molten two millimetre diameter glass rod should be resorted to.

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